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PROCEEDINGS

OF THE

ENGINEERS' CLUB

OF

PHILADELPHIA.

ORGANIZED, 1877.

VOL. IV.

PHILADELPHIA:
PUBLISHED BY THE CLUB.
1884.

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PHOTOTYPE F. GUTEKUNST PH'LA'A.

Henry G. Morris.

PRESIDENT DURING THE SIXTH YEAR OF THE CLUB, A. D. 1883.

PROCEEDINGS
OF THE
ENGINEERS' CLUB OF PHILADELPHIA.
ORGANIZED DECEMBER 17th, 1877.

SECOND GEOLOGICAL SURVEY
PENNSYLVANIA.

NOTE.—The Club, as a body, is not responsible for the facts and opinions advanced in its publications.

Vol. IV.] MARCH, 1884. [No. 1.

ANNUAL ADRESS

OF HENRY G. MORRIS, Retiring President.

Read January 12th, 1884.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

GENTLEMEN: At the close of the sixth year of our organization, it is my privilege to attempt a brief resumé of the most important engineering works which have been in progress or completed during the past year.

The details of all such works are so fully brought before you, either in your own experience or through the medium of the numerous engineering publications, that I will not attempt to enter upon any extended descriptions, but merely name the principal works in their apparent order of importance.

From the magnitude of the labor involved, and their important bearing on the future commerce of the world, *Canals* appear to have taken a foremost position, that of the Isthmus of Panama being, of course, most prominent.

Under the energetic direction of Count de Lesseps, the work has so progressed that some 14,000 laborers, with the assistance of dredging machines of great power, are now engaged in moving about 300,000 cubic yards of material per month, but when it is considered that the completion of the work in 1888, as has been promised, will require the handling of ten times this amount, and that many uncertain difficulties are to be encountered, it may

well be doubted whether the expectations of the promoters of the scheme will be realized within the time named.

The canal through the Isthmus of Corinth, 21,140 feet long, requiring the removal of 13,000,000 cubic yards of material, at an estimated expenditure of 25,000,000 francs, is progressing under the charge of German engineers and French contractors; the deepest cutting being 260 feet, and the contract time for completion being three years.

The present Suez Canal having proved inadequate to accommodate the constantly increasing traffic through it, which has already reached ten million tons per annum, the Board of Control have decided to double its capacity by forming a new basin at Port Said, and widening and deepening the canal at various points.

The English capitalists, jealous of the controlling influences of the de Lesseps interests, are of the opinion that it would be better to make a second canal at an estimated expenditure of $160,000,000, in which case, each would become a "one way" canal. As illustrating the progress of commerce by this route, it may be stated that, in 1880, the tonnage was 4,344,000; in 1881, 5,794,000; in 1882, 7,122,000.

The scheme of cutting a canal, 50 miles long, from the river Mersey to Manchester, to convert that busy manufacturing city into a seaport, has been vigorously opposed by the Railway Companies, as well as the Mersey Harbor and Dock Boards of Liverpool.

Manchester being 60 feet above sea level, three locks would probably be required.

Work upon the canal through Cape Cod has been commenced, but, from a lack of funds and want of management, is not being pushed with any vigor.

The canal across the Florida Isthmus will hardly command the required capital of $46,000,000, the trade, now or prospective, not warranting such an outlay, and the scheme is generally regarded as belonging to the field of so-called "financial," rather than engineering operations.

Among other canal schemes may be named, that from Bordeaux to the Mediterranean; between the Baltic and North Sea, first

proposed in 1571; from Dublin to Galway in Ireland; on our own side of the water, across the Maryland Peninsula, and last but not least, the project to flood the vally of the Jordan by means of a canal from the Mediterranean, submerging an area of some 2800 square miles, including Bethsaida, Capernaum, Tiberias, Plain of Genessaret and Jericho. The Dead Sea part of the system is 1312 feet below sea level, covering an area of 500 square miles. Cuttings 728 feet deep in some places would be required, and as the estimates of the time required to fill the area with water, vary from nine months to 100 years, it may safely be assumed that no very definite data have yet been determined upon.

Under the head of tunnels, the most important work completed during the year has been the tunnel of the Arlberg, between Austria and Switzerland, 6½ miles in length, which has been excavated at the rate of 7,080 feet per year, as against 5,474 feet per year for the St. Gothard, and 3637 feet for the Mt. Cenis. The cost of the Arlberg tunnel has been $750 per metre; St. Gothard, $1250; Mt. Cenis, $2000, thus showing the advance made in the use of rock drilling machines.

In England the tunnel under the River Severn was drowned out in October by the re-outbreak of the leak of 1879, and thus far the pumps have not gained on the leak; previous to the last break as much as 12,000,000 gallons of water had been raised daily. The total length of the tunnel when completed will be 4½ miles, 2½ of which are under the Severn. The Mersey Tunnel, commenced in 1881, has progressed satisfactorily, one-half of the total length of 3 miles having been driven by September, 1883.

The "Beaumont" boring machine previously employed on the Channel Tunnel, is now in use under the Severn, and is advancing the heading at the rate of 1 foot per hour, cutting the full area of the heading, 7 feet in diameter. In the chalk under the Channel this machine advanced at the rate of 6 feet per hour, and cut 15,000 feet of heading there.

Owing mainly to political considerations, the work on the tunnel under the British Channel has been abandoned.

The piercing of the Alps, under either Mt. Blanc or St. Bernard, is being discussed in the Italian journals, and it is likewise proposed to unite Italy and Sicily by a tunnel of 13,546 metres in length.

Returning to our own country, we find that work on the Hudson River Tunnel has been suspended, owing to lack of funds and doubts as to the ultimate success of the method in use. 1,700 feet on the New Jersey end and 200 feet on the New York shore have been completed, or one-third of the total length.

The Boston Sewerage Tunnel under Dorchester Bay was entirely completed in June, 1883, and on the first day of the present year the pumps were put in operation. An examination of the completed work shows evidence of the great care and faithfulness of design and execution, reflecting the highest credit upon all concerned therein. Indeed the whole project from its inception to its completion is a triumph for American engineering, even outranking the famous system of Paris in the opinion of French engineers. Its primary object, as is well known, is the interception of the sewage as it now flows in the existing sewers, by a main beginning at Camden St. and Huntingdon Ave., and running to Old Harbor Point, where it terminates in the main pumping station; the sewage here first passes through "a filth hoist," to get rid of any large floating objects that might injure the pumps, of which there are four, with an aggregate capacity of raising 100,000,000 gallons each twenty-four hours to a maximum height of 43 feet. From this point, the outfall sewer extends to the reservoir on Moon Island, a distance of 13.750 feet, of which the tunnel under Dorchester Bay takes up about 6,970 feet in horizontal length, and forms with its west shaft an inverted siphon, which has, at first, a vertical descent of about 150 feet, then a horizontal stretch of about 6,070 feet, and finally a rising incline of 1 foot vertical to every 6 feet horizontal. At Moon Island the sewerage is discharged into a large reservoir, capacity 25,000,000 gallons, where it will accumulate during one tide, and be conveyed to the open harbor at the end of the Island, being discharged two hours after the ebb tidal currents are established. The total cost of the system has been about four and a half million dollars.

Upon the completion of the work and its first practical test on New Years day, the recorded results were in advance of the most sanguine expectation of the engineers. It was found that the sewerage from West Roxbury, the Highlands, Beacon Hill, etc.,

was passing through the main sewer at the rate of 3½ feet per second, much higher than the anticipated velocity, and that so rapidly can the final reservoir be emptied, that the entire daily sewage of the city passes out to sea in a strong, straight current, within one hour after the gates are opened.

On the line of the Southern Penna. R. R. seven tunnels, varying from 6,700 to 4,300 feet in length, are now under contract, to be completed within two years, and are the most important works in this branch of engineering now in progress.

The great East River Suspension Bridge was formally opened on the 24th of May, 1883. The total cost has been $15,700,000. With the details of this work you are already familiar, so that it is not necessary to refer to them. In running the cars over the bridge some difficulties have been encountered in obtaining a sufficient "grip" on the endless cables to propel the cars, which appear to be needlessly heavy, and owing to the proximity of the Chatham St. Station of the Elevated Railway, at the New York end, there is insufficient room to handle the cars to advantage.

On the 20th of December, 1883, the "Cantilever" Bridge over the Niagara River was formally opened, the work having been really completed on the first of the month according to contract, which was entered into only seven months previously. This bold structure spans the river by two cantilevers, having river arms of 175 feet length each, and one suspended span of 120 feet; the base of rails being 239 feet above the water.

Another important bridge about to be constructed, is that of the new Baltimore and Ohio R. R. across the Susquehanna River above Havre de Grace.

In England the bridge over the Frith of Forth is in progress, but at the present time only the viaduct piers are in place. The two deep water spans are to be 1,700 feet each, cantilever construction, centre arms approaching within 500 feet of each other; the main compression members are steel tubes, and the structure is calculated to bear a wind-pressure of 56 pounds per square foot.

The construction of the new Tay Bridge has been commenced, the location being 90 feet above the old site. The spans will vary in length from 66 to 245 feet; roadway 77 feet above tide; the

deep water piers will be wrought iron cylinders and the lattice piers will also be of wrought instead of cast iron, as originally designed.

The past year has witnessed the completion of another highway across the Continent; that of the Northern Pacific R. R., opening for settlement a vast territory which is rapidly attracting emigrants of the best class, and destined at no very distant day, from its great agricultural and mineral resources, to play an important part in the increasing prosperity of the great Northwest.

The Canadian Pacific R. R. is progressing rapidly, judging from the anouncement made at the Convention of the American Society of Civil Engineers, at St. Paul, in June of the past year, where it was stated that $25\frac{8}{10}$ miles of track had been laid in six days.

The railways now building in Mexico had reached, in April, 1883, a total of 2379 miles, and their completion will doubtless rapidly develop the trade between the two countries, now awaiting the stimulus of American enterprise and capital.

The New York, West Shore and Buffalo R. R., recently opened, attracts attention from the high character of its construction and the great care and system displayed in its engineering departments.

The Southern Penna. R. R., now partly under contract, shows most thorough preliminary surveys, never equalled for the area of country along the line investigated.

The proposed Ship Railway of Capt. J. B. Eads, across the Isthmus of Tehuantepec, has not yet been commenced, but Capt. Eads is sanguine of his ability to obtain the necessary capital in England, and expects to have the work finished within five years. Surveys have been completed and the route found much better than had been expected. This is the first complete, connected line of instrumental survey ever run across the Isthmus.

The "Railway Exposition" held in Chicago, in June, 1883, was of the most interesting character and was probably the best class exhibit ever made in this country.

In railway building there appears to have been a great reduction in number of miles constructed; the total in 1883 up to November being 4,626 miles, as opposed to 11,591 miles in 1882, and a little over 9,000 miles in 1881. The estimated total for

1883, is 6,300 miles. Total U. S. mileage to the close of 1883, 113,329. Total share capital now $3,500,000,000 in round numbers; gross earnings for 1882, $770,000,000, being an increase of $67,000,000 over 1881.

The method of propelling cars on street railways by means of endless cables actuated by stationary engines, appears to be growing in favor, a short line having been put in operation in this city, and an extension of the system to various other roads being proposed; the experience on the Chicago lines, as stated by the managers, shows that the running expenses are reduced one-half by the system, as compared with the use of horses, and that three times as many cars are now operated as formerly.

To lay a telegraphic cable across the Atlantic no longer appears to be the formidable work which confronted the engineers of twenty-five years ago, for two new cables have been contracted for recently, the first to be ready for work by June of the present year.

In the field of electricity, no startling discoveries have been made recently, but under the pressing demand that the wires which now so disfigure our streets, shall be placed underground, a variety of methods have been proposed, the most promising of which seems to be that recently laid on Chestnut St., in this city, the conduit being of sufficient capacity to accommodate a large number of electric light, telegraph and telephone wires, and at the same time, ample means for replacement of any wire are provided. The mechanical details seem to have been well considered, and the reports of its success in Chicago where several miles have been laid, would appear to show that the problem of getting rid of poles and wires on our streets has been solved in one way at least.

It is unfortunate that the authorities in New York City, have, in the face of much popular opposition, granted the Telegraph Companies two years immunity from the threatened enforced burying of the wires, a privilege which will doubtless be prolonged to its extremest limit, that the companies may avoid, as long as possible, the great expense of so radical a change in their wires and general system. It is doubly unfortunate that this prolongation of the nuisance should exist in the largest city of the

Union and headquarters of the principal electrical companies, as they will not feel impelled to give to this question the experiment and invention necessary under adverse circumstances. Setting aside entirely the unsightliness of the present arrangement, it is impossible to continue to ignore the great danger to life and property, where electric lighting wires, subject to many forms of accident, are supported on poles in the streets of a great city.

In the matter of telephones, no great improvements have been brought forward, but it is worth while perhaps to note that the claims of the principal company as to its priority of invention on nearly every improvement used in this branch of business, have been attacked by rival companies, and evidence is not wanting that several new systems will be introduced and developed at no distant day.

In telegraphic improvements, perhaps one of the most interesting is the substitution, for the old iron wire, of the compound wire of copper and steel now in use by the Postal Telegraph Company, who claim for it so much greater conductivity, that, used as a telephone wire, it enables operators in New York to converse with those in Cincinnati without difficulty.

It is worthy of note that no progress is evidenced, in this county at least, of the principle of storing or accumulating electricity by the Faure, Planté or any other process; on the contrary, the attention of our engineers appears to be directed in the opposite direction, looking to improvements which shall give to the arc and incandescent lights, without the intervention of a storage battery, many of the properties claimed for the lamps lighted from an accumulator.

Recently, experiments have been made in France on the subject of lighting railway cars by electricity developed by the motion of the train, but with no great success, for notwithstanding the assistance rendered the dynamos by an elaborate system of accumulators, it was demonstrated that while the speed of the train was maintained at the rate of 37 miles an hour, the light was brilliant and constant, but a diminution of that rate affected the lamps so seriously that at 16 miles per hour they were extinguished.

The subject of Electric Railways is attracting considerable attention both in Europe and America, but on this side of the Atlantic nothing practical has so far been accomplished; while the scheme is undoubtedly feasible, at present the great cost of developing the required power, seems to preclude its use from an economical standpoint.

An Electrical Exhibition on a more extended scale than any one hitherto attempted in this country, will be inaugurated in this city next fall, and will afford a most interesting opportunity to mark the improvements which have been made since the date of the one held in Vienna last year.

Since our last annual meeting, the electric world has been called upon to mourn the death of Dr. Siemens, whose researches and inventions in this branch of science have earned for him pre-eminence even amongst those brilliant men who have made it their life study. He was indeed a connecting link between the theories of gas lighting and of electric lighting, and by his very course of action regarding them, gave an indication of what is fast becoming an accepted fact, that, though rivals, their rivalry will be a friendly and beneficial one, not inimical. We must not forget, that having achieved such fame as an electrician, he again turned his attention to the subject of illumination by gas, well recognizing the fact that the "light of other days" should not be relegated to the past, but so improved that it would be able to hold its own against the new competitor.

The result of his labors was the Siemens' Regenerative Gas Burner, a specimen of which is now in nightly use at the Hotel Lafayette in this city, where its relative economy is demonstrated by the fact that, although consuming 50 feet of gas per hour, it has displaced the multitude of ordinary burners which were using 180 feet per hour. The result of his labor may then be aptly regarded as the epitome of the history of gas-engineering for the past five years, the improvement already introduced in that period having effected an economy of well nigh one-half as regards previous cost. It is safe to assume that with this past experience as an earnest for the future, the day is not far distant when the use of gas for all domestic purposes, at least, will take the place of our present methods of obtaining heat from solid fuel.

The efforts of the various gas companies in their demonstration of this and other properties and uses for their product, are almost as ingenious as the inventions they bring forward. This was particularly noticeable in the exhibit of the gas companies at the Toronto Exposition held last September, where one-fifth of the buildings were allotted to them for illumination; several very large burners were introduced for that purpose, among others a 1000 candle Siemens Burner, and an 800 candle Bray Lantern. Much attention was attracted by the many devices in gas-stoves both for heating and cooking, and for the instruction of the public each stove had a card attached to it, on which was written such information as would be of interest, such as price of stove, consumption of gas per hour, and cost of same; size of family, that the stove was suitable for, or if a heating stove, the size of room it would properly heat.

Such exhibitions as these will undoubtedly hasten the day when gas will be used to an extent hitherto deemed impossible.

In the matter of steam heating by means of pipes running through our streets, Philadelphia has made no progress, although one of the companies, whose work in New York has given great satisfaction, has endeavored to gain the consent of our authorities for a trial of its system in this city, but has encountered very much the same kind of opposition as did the pioneers of the system of lighting our city by gas, forty years ago.

The failure of one of the New York companies on account of inadequate engineering, mechanical and financial ability, has doubtless been prejudicial to the interests of the succesful one, owing to a misconception that the systems were identical. The plant of the New York Steam Heating Company was so thoroughly described in the preceeding Annual Address, that I need not here refer to the details. There are now in operation over five miles of this company's mains under the streets of New York, in hourly use, and with apparent great satisfaction to the consumers. The relative cost of buying one's steam or of making it on the premises, is, according to the tariff of rates charged by this company, very nearly similar; but allowance must be made in favor of the supply company, for the original cost of the individual plants, the wages of workmen to run them, the expense of

removing ashes, etc., to say nothing of the far greater danger of explosions, to be apprehended from a boiler under each sidewalk, perhaps inadequately attended by a tyro of an engineer, rather than from an aggregation of these boilers in one building under the constant charge of experts.

The year 1883 has witnessed the completion of Bartholdi's statue of "*Liberty Enlightening the World,*" and it is to be hoped that no further delay will be experienced in providing the means wherewith to build its pedestal and foundations on Bedloe's Island in New York Harbor, but so far only one-half of the amount needed, $250,000, has been raised, and the foundation has but reached the level of the ground; up to the terrace level this will be of solid concrete, 90 feet square on the bottom, 65 feet square on the top, and 52 feet 10 inches in height. The pedestal proper is to be 62 feet square at the bottom, 40 feet at the top, and 114 feet to the base of the statue; its material will be cut stone throughout, although the kind has not yet been determined.

The copper sheets used in forming the statue are about one-eighth of an inch in thickness and are firmly attached by interior ribs, straps and forgings to a strong four-sided iron frame, which occupies the centre of the figure and will itself be firmly anchored to the masonry of the pedestal. The weight of the copper in the figure is 176,000 pounds, and of wrought iron 264,000. Its total height to the top of torch is 151 feet, which, added to that of the pedestal and foundations, will give it an altitude of 324 feet above low water mark.

On November 18th of the year just passed, was witnessed the adoption of the new time standard by most of the railroads in this country, and consequently by nearly all the towns and cities through which they pass; with the details and reasons for this important movement you are so familiar, that I will refer merely to the general satisfaction expressed as regards the new system, except, indeed, in those cities so nearly on the border line between two standards that they enjoy in reality three times, one true and two fictitious, but as the divergence is always an even hour, no more confusion is likely to arise than formerly obtained in, say Pittsburgh, where they had true time, Pennsylvania R. R. time, and that of the Pittsburgh, Fort Wayne and Chicago Railway.

The important work of the Geological Survey of the State of Pennsylvania, with which a number of the members of our Club are connected, has made satisfactory progress, as evidenced by those reports already published, and the papers which have been read before you.

In marine engineering, the most noticeable features have been in the increased size and speed of the Trans-Atlantic steamers recently built. The introduction of corrugated fire-boxes having rendered it safe to carry much higher steam pressures on the boilers than formerly, other improvements, looking to a more economical use of the steam, naturally followed; the result being that the "Alaska" and "Oregon" are making the voyage regularly in about eight days, and there would seem to be no doubt that we may soon have "express lines" of steamers established, which will make the passage from America to Europe within the limits of one week.

The designs for the new war vessels about to be built for the U. S. Navy, have been the subject of considerable criticism at the hands of authorities on such matter, both here and abroad, and it is to be hoped that such modifications will be made in the plans as will insure that the vessels, when completed, will be fair examples of what can by accomplished by American engineering talent in that line.

Having thus briefly referred to some of the principal events of interest in the engineering world, as they have occured to me, it only remains to thank you for your unvarying courtesy to me as President, to trust that the prosperity of the Engineers' Club of Philadelphia may continue in an ever-increasing ratio, and to wish you all God-speed.

OPENING ADDRESS

of Col. William Ludlow, President.

On taking the Chair for 1884.

Presented January 12th, 1884.

Gentlemen of the Engineers' Club of Philadelphia:

I thank you most warmly and sincerely for the honor you have done me in electing me as your President for the year 1884.

The rank which the Club has so rapidly acquired among similar organizations, the character of its Membership, and particularly the high reputation of your Past Presidents, all combine to make the position one of no less honor than responsibility.

It will be my duty and my pleasure, so far as may be, to maintain and advance the interests of the organization in every way possible, and to use my utmost endeavor not to fall short of the high standard set by those who have preceded me. The status of the Engineering Profession among the higher agencies of civilization is to-day unquestioned. The Engineer is at once the precursor, the concomitant and the mainstay of human progress, and while the world shall continue to go "down the ringing grooves of change," it is the Engineer who must build the grooves, furnish the impetus and lead the way. It remains for us, of this generation, to do our part fearlessly and conscientiously, to make the future better than the present.

You will not expect much at this time from me in the way of suggestion, but there are one or two points which I desire to present:

First: To improve the standing of the Club, both professionally and socially, here at home, in order that its usefulness to the best interests of the City and State may be developed. The Engineers' Club might well be a recognized organization from which, when occasion arises, both advice and assistance could be sought and rendered to the City of Philadelphia and to the State at large.

Secondly: It seems to me that the time must shortly come when the Club shall have its permanent abiding place and home, to which all its Members can resort, both for study and compan-

ionship, and where due provision can be made for its library, reading rooms and general offices. Such a place can readily be found at a moderate increase of rental and in a locality entirely central and convenient.

I shall confidently look forward to and rely upon the fullest co-operation of all the Members in advancing the interests and usefulness of the Club during the ensuing year, and again thanking you for the distinguished consideration you have shown me, beg to assure you, collectively and individually, of my sincere regard and appreciation.

STRICKLAND KNEASS.

The Engineers' Club of Philadelphia, record with sincere regret, the loss of one of its most distinguished and valued members.

Its late President, Mr. Strickland Kneass, died at his residence in this, his native city, January 14th, 1884.

Mr. Kneass was born July 29th, 1821; his father, Mr. William Kneass, was an engraver of considerable eminence, and for many years employed in that capacity in the United States Mint.

Mr. Kneass' early education was obtained chiefly under the tuition of Mr. James P. Espy, who was one of the first to suggest the present methods of indicating and anticipating changes in the weather.

When quite young Mr. Kneass decided to adopt the profession of Civil Engineer, and commenced his career and practical training as such, upon the surveys then making for the Delaware and Schuylkill Canal, of which his elder brother, Mr. Samuel H. Kneass, was then Chief Engineer; and later assisted in the surveys and construction of the Philadelphia and Wilmington Railway. Upon the completion of this road he became a student in the Rensselaer Polytechnic Institute, at Troy, New York, whence he graduated in 1839 as Civil Engineer, taking the highest honor.

Mr. Kneass was soon after made Assistant Engineer and Topographer on the State survey for a railway between Harrisburg

and Pittsburg. He then became draughtsman in the Naval Bureau of Engineering at Washington, and was afterward employed by the British Commission in preparing the maps of the Northwest boundary, between the United States and the Provinces; and subsequently by the Federal Government on the general map of the boundary survey.

At a later date, 1869, he was appointed, jointly with Colonel James Worrall, a Commissioner to settle the boundary between Pennsylvania and Delaware. The line is the arc of a circle of about twelve miles radius; to locate such permanently and correctly required great care, for the accomplishment of which Mr. Kneass' remarkable thoroughness peculiarly fitted him. The proposed line, however, was not accepted by the Delaware Commissioners.

In 1847 Mr. Kneass was selected by J. Edgar Thomson, Chief Engineer, as one of his assistants in conducting the preliminary surveys and explorations which resulted in the construction of the Pennsylvania Railroad; he was soon promoted to the position of Principal Assistant Engineer, and engaged in the construction of that part of the road from Jack's Narrows to Tyrone, including the river bridges and Tussy Mountain Tunnel.

The first shops and engine house erected by the Company at Altoona, were from his designs.

The construction of the road from Altoona to the summit of the Alleghenies was a work of much difficulty, and called forth engineering ability of a very superior order, in the accomplishment of which Mr. Kneass proved himself fully capable.

In 1853 he resigned to accept the position of Associate Engineer with Mr. Edward Miller, Chief Engineer of the North Pennsylvania Railroad, in which capacity he remained two years, leaving to accept the office of Chief Engineer and Surveyor of the newly Consolidated City of Philadelphia, to which position he was elected by the Select and Common Councils, on March 29th, 1855, and subsequently re-elected three times, namely, on April 12th, 1860; April 13th, 1865, and April 14th, 1870, each for a term of five years.

The surveys and plans of the various old Districts had been made by surveyors elected by their respective Commissioners,

without any general directing head, and after being confirmed by the Court were filed in the office of the Clerk of the Court of Quarter Sessions. Many valuable papers relating to streets and surveys of the old Districts were found stored indiscriminately in the Tobacco Warehouse. Mr. Kneass had all these plans and papers examined, indexed and filed, bringing order out of chaos.

Throughout the old Districts, sewers were located and their dimensions fixed by the Boards of Commissioners, without any regard to grades or the areas to be drained; in many cases the sewers were, of course, totally unsuited to the demands made upon them.

Mr. Kneass had a map prepared showing, as far as possible, the existing sewers with all the drainage areas carefully computed, from which could be determined with certainty the location and size of any new sewers that might be needed; after mature deliberation he adopted a standard formula applicable to all the questions of sewerage that might arise.

The surveys of the old Districts were made by various standards of measure, all of them differing from the United States standard, and, as a large proportion of the City was yet to be laid out, he used his best efforts to have the United States standard adopted for all future surveys, and to reduce those already made thereto; in this, it is now much to be regretted, he failed, as it cannot be done now, the surveys having extended to such proportions as to make it impossible.

In 1857 City Councils directed him to advertise for designs for a bridge over the river Schuylkill, at Chestnut Street, offering premiums for the best three, their merits to be decided by a commission consisting of J. Edgar Thomson, Ashbel Welch, and John C. Cresson; it was stipulated that the plans should be known by private marks, the names of the designers appearing only upon the accompanying papers similarly marked and sealed.

Mr. Kneass, believing it his duty as Chief Engineer of the City, to present a design, prepared one of a cast-iron arch, and submitted it among the many others. This plan was selected by the commission as the most appropriate for the location and recommended to Councils for its adoption. Mr. Kneass declined to accept any premium, and recommended the commission to select in their judgment the next best three for that purpose.

This design having been approved by the Board of Surveyors and adopted by Councils, he at once had prepared the necessary detailed plans for the masonry and superstructure; and, after some delay on the part of Councils in arranging for the necessary funds, contracts were entered into for its construction.

Mr. Kneass advised the Committee of Councils to fix the width of the bridge at about eighty feet, to correspond with the street on the west side of the river; but they assumed that, as the street upon the east side was practically only forty-two feet, it was unnecessary to make the bridge any wider.

He also recommended that the eastern approach begin at Twenty-second Street, instead of Twenty-third, and the western approach end at Thirty-first Street, instead of Thirtieth, as adopted; the improvements of the property upon the line at that time were of such a character as to cause but little damage, while the improvement to the approaches would have been a great permanent advantage, as can be understood at this time; plans and estimates were made for this purpose, but in these propositions he was overruled by the authorities because of the expense. The construction of this cast-iron bridge was believed to be the first of the kind in this country, and, at the request of the officers of the Franklin Institute, of this city, Mr. Kneass furnished a paper explanatory of the general features of its construction, which, with illustrations, can be found in the Journal of the Institute, Vol. XLIX, 3d series, page 413.

About the year 1860 a skeleton Burr truss bridge was built upon the piers and abutments of the old toll bridge across the Schuylkill, at Falls Village, the amount appropriated by Councils not being sufficient for a more finished structure.

Previous to the year 1865 there was no record or plan in this city by which a citizen could, in any reasonable time, ascertain the ownership or dimensions of an individual property. Under an Act of Assembly passed in March of this year, Mr. Kneass organized and, on July first of the same year, put into successful operation, what is now known as the Registry Bureau. By a very simple system of plans and records, arranged in book form, any citizen can, in a few minutes, obtain all this information, in reference to any lot in the city, and at the same time a brief of title

extending to one ownership prior to that of 1865. The original intention of the Act was "To promote the more certain and equal assessment of taxes," but its value and importance to the general public, as a record of ready reference, has caused it to outgrow its original design—it is to-day one of the most useful Departments of the City.

The system has been adopted by other cities, and without any attempt to improve upon it. The commission appointed by authority of the Legislature to examine and report upon a system of government of cities and towns in the State, after careful examination of the practical workings of the Registry Bureau, recommended the adoption of a similar system throughout all the cities, towns and boroughs of the State.

In 1866 an Act of Assembly was passed appointing a commission to build a bridge across the river Schuylkill, at South Street, under the general supervision of Mr. Kneass, as Chief Engineer and Surveyor of the City; they advertised for plans and proposals in accordance with general outline plans, fixing the location of the superstructure and approaches; three plans were submitted and referred to Mr. Kneass to report upon their relative merits; he recommended the adoption of the plan submitted by Mr. John W. Murphy, with certain modifications, among them the substitution of short-span iron girders, supported by piers or wrought-iron columns, for the series of stone or brick arches over the marsh and meadow on the western approach, with his reasons therefor; these modifications were approved by the commission, but by some subsequent action, not clearly shown upon their minutes, the series of brick arches were constructed; the present ruins are a monument to their folly, and confirm the correctness of Mr. Kneass' views as expressed in his report.

Under a resolution of Councils, passed April, 1868, Mr. Kneass was directed to prepare plans and estimates for bridges over the Schuylkill at Bridge Street and Powelton Avenue. He reported upon plans and estimates for both sites, but recommended placing, upon the site of the old wire suspension bridge, a double roadway truss bridge; the lower roadway connecting Callowhill Street on the east with Thirtieth Street on the west; the eastern approach to the upper roadway was located upon the side of the

Fairmount reservoirs, commencing at Twenty-fifth and Spring Garden Streets; the western approach crossing above the track of the Pennsylvania Railroad, extending to about Thirty-second Street.

This general plan was approved by Councils, October, 1868, and he was directed to advertise for detailed plans for the main superstructure, and the plan selected by the experts appointed for that purpose was approved by Councils, January, 1870. So much time was consumed in the necessary legislation by Councils, in authorizing a loan and making the appropriation, that the contracts for the erection of this bridge were not fully entered into and the work begun until after he had resigned his position as Chief Engineer and Surveyor; but his original plans were fully carried out by his successor.

During the late war, 1862, in company with the late Colonel C. M. Eakin he was engaged in making a reconnoissance of the military approaches to the City, extending along the Susquehanna River to Havre-de-Grace; the report of this work in the field and the accompanying maps, were, at the time of Lee's last raid into Pennsylvania, highly useful to the Government, but more particularly to Gen. D. N. Couch, Commander of the Department of the Susquehanna, which included this City. This report, with the maps, are deposited in the office of the Department of Surveys.

In 1871 he was selected as one of the two engineers to make a survey, and report upon the best means of draining or culverting Jones' Falls, Baltimore.

The first Passenger Railroad in this City, the Fifth and Sixth, or Frankford and Southwark Road, was built under the direction of Mr. Kneass, who then established the form of tram rail now in use by all the passenger roads in the County. He was Chief Engineer of many of the passenger railroads in this City.

During Mr. Kneass' term of office he was officially one of the Commissioners of Fairmount Park, and rendered essential service in that capacity, his knowledge of the ground covered by the Park, and its surroundings, being very useful in deciding questions connected therewith.

In April, 1872, Mr. Kneass resigned his position as City Engineer, to accept the post of Assistant to the President, J. Edgar Thomson, of the Pennsylvania Railroad, and subsequently occupied the same position under Thomas A. Scott, and Mr. Geo. B. Roberts, the present President. In connection with the road he was the President of the following: Belvidere Delaware Railroad, Columbia and Port Deposit Railroad, Freehold and Jamesburg Agricultural Railroad, Lewisburg and Tyrone Railway, Mifflin and Centre County Railroad, Philadelphia and Trenton Railroad, Pomeroy and Newark Railroad, Philadelphia and Long Branch Railroad, River Front Railroad, Cresson Springs Company, New Jersey Warehouse and Guaranty Company, and was Director in the Boards of forty-four of the Companies connected with the interests of the Pennsylvania Railroad Company.

During the year 1881, Mr. Kneass served as President of this Club, and by urbanity of manner endeared himself to the members who had the pleasure and advantage of meeting and becoming acquainted with him.

He was a member of the "American Society of Civil Engineers," the "American Philosophical Society," the "Franklin Institute," and "Historical Society;" was one of the earliest members of the Union League, of this City, and one of its Board of Directors from December, 1879, to December, 1883.

In 1853 he was married to Margaretta Sybilla, grand-daughter of the Hon. George Bryan, of the Supreme Court of Pennsylvania.

Mr. Kneass was a sincere Christian, a member of the Tabernacle Presbyterian Church. In 1856 was elected member of the Board of Trustees; acting as Secretary until 1872, when he became President.

His principles of honor were of the highest character, just and impartial, a warm, reliable friend. As a public officer most carefully guarding the interests of his employers, whilst at the same time he was mindful of the rights of the employé or contractor. With sound, good judgment, he was looked up to by those requiring his advice, always freely given. He was genial, and his courteous demeanor towards all classes, inspired respect from those with whom he came in contact.

HOWARD FRY.

Howard Fry, Superintendent of Motive Power of the New York, West Shore and Buffalo Railroad, and a Corresponding Member of this Society, was killed April 27th, 1883, in a collision on the Grand Trunk Railway, near Bellevue, Mich.

His death was not instantaneous, but, although he retained the use of his faculties long enough to direct the efforts of those who sought to extricate him from the wreck of the sleeping car, he became unconscious shortly after his removal, and his last few hours were probably painless.

He was born in England, of Quaker ancestry, and began his railroad experience as a "gentleman apprentice" in the Ashford shops of the Southeastern Railway. When he had completed his apprenticeship he was appointed assistant foreman and locomotive inspector at the London shops of the same company. In March, 1867, he came to Canada as a locomotive inspector on the Grand Trunk Railway, and in January of the following year he became assistant mechanical superintendent of the Eastern Division of the same road. This division is located in the State of Maine, and it is characteristic of Mr. Fry that he did not share the prejudices which existed among some of his associates against serving among the "Yankees," and gladly accepted a position on what he considered then the best equipped and best managed part of the road.

In 1873 he was appointed supervisor of locomotives on the Erie Railroad, and was in charge of the company's shops at Susquehanna depot during the great strike which brought all business on that part of the road to a standstill, and for a time threatened the most serious consequences. The shops were stopped, no freight was allowed to pass, and the sidings and yard were filled with trains which could not be moved. It was a time of the greatest anxiety; the local authorities were apathetic, powerless or in sympathy with the strikers, and a request for troops brought a few militiamen from the neighboring counties, undisciplined, poorly equipped and not thoroughly under con-

trol. Their presence was an additional care and a great source of anxiety to Mr. Fry, for, although there had been but little actual violence and no bloodshed, the attitude of the strikers was so menacing that he felt sure that any indiscreet or hasty action of these soldiers might precipitate a bloody riot or lead to the destruction of an immense amount of property. At this juncture the First Regiment of the Penna. National Guards, under command of Col. Benson, arrived from Philadelphia. They disembarked about a mile from the town and, marching into the shops quietly, took possession of all the railroad property. Mr. Fry never forgot the services they rendered, and was loud in praise of their soldierly conduct. No regulars of any standing army (he used to say) could have done the work in better fashion; and he has often told the writer that when he saw them march into the yard at Susquehanna he felt that the strike was over. And so it proved to be, for no opposition was offered to so formidable a body of men. At a meeting then held the strikers agreed to return to work, and the miles of cars that occupied the tracks were slowly put in motion.

Although Mr. Fry opposed the strikers at every step, even at the risk of his life, his just and manly treatment won their respect; and whenever, in subsequent years, he passed through Susquehanna, there was always a crowd of the old "hands" ready to board the train for a few kindly words with him. When the train bearing his body stopped there, these same men placed on his bier a basket of flowers bearing the words "Not Forgotten." A change in the management of the Erie road led Mr. Fry to resign his position, and he was next appointed to be superintendent of motive power and machinery on the Philadelphia and Erie Division of the Pennsylvania Railroad, with headquarters at Williamsport. This position gave him considerable independence of action, but at the same time brought him directly under the controlling influence of the Pennsylvania Company, and enabled him to become conversant with the system of that great organization. He was also permitted to revisit England and inform himself thoroughly of the best practice of the English railroads. He became an enthusiastic admirer of the American railroad system as represented by the Pennsylvania Company,

and an earnest defender of the American type of locomotive; but at the same time he thought he saw much in the English engine and the English road, which he believed might be profitably adopted in this country. For example, he claimed that too little attention had been paid to economy in fuel and that the time had now come when a higher efficiency should be developed.

He remained on the Philadelphia and Erie Railroad until September, 1881, when he accepted the appointment of superintendent of motive power and machinery on the New York, West Shore and Buffalo Railway. This road was a new one, and he was expected to design or select the rolling stock, shops and equipments.

The opportunity thus offered him was exceptional, for the road projected was to be a great one, no expense was to be spared to make it complete in every detail, and he accepted his task as the crucial test of his knowledge and ability. He held pronounced opinions, and in building up an entirely new road he hoped to start with many innovations that could not be introduced on an old established road except in the most gradual manner; but at the same time he realized that there was neither time nor opportunity for experiments, and that he could only deviate from the usual practice where he thought himself absolutely sure of success. In designing his locomotives he dispensed, as far as practicable, with all means of adjustment which could be abused by an ignorant or careless runner so as to destroy the proper relations between the various parts. With this object in view he followed the practice of Ross Winans and others, and constructed his rods with solid ends instead of the usual stubs with key adjustment, but he increased the diameter of the crank-pins to obtain greater wearing surface, while, instead of the usual adjustable piston packings, he used the simple split Ramsbottom rings which cannot be altered. He restricted the engines used to four classes, and designed these so that the greatest number of parts should be common to all. He had the courage of his convictions, and, in spite of American prejudices to the contrary, he dispensed with all useless ornamentation and fashioned dome and smoke-stack somewhat after the severely plain, but very sensible, English

model. In planning the principal shops he had constantly in view their possible extension in any direction as the growing or changing needs of the road might demand; he therefore arranged the various departments radially to a common centre, so that any one can be conveniently enlarged without destroying the architectural symmetry of the whole group. He favored driving by small independent engines in each department or shop, rather than by a large engine centrally situated, because of the convenience with which any part can be economically run alone. In the first four or five small repair shops built, Westinghouse engines mounted upon piers were coupled directly to the line shafts.

Mr. Fry devoted himself with ardor to the elaboration of the multitude of details which required his attention; labored conscientiously and unremittingly, and was killed just when he had every reason to believe his work would soon be crowned with a success that would establish his reputation upon the broadest basis and reward his labor with an acknowledged eminence in his profession and comparative ease. Such a death in the prime of a vigorous manhood is always sad, but in his case the sadness is inexpressible. He was stricken down in robust health at a time when the future appeared particularly bright to him, and when the oldest of his four little children was just reaching that age when a father's care and example are most necessary.

Shortly after Howard Fry's death the *Railroad Gazette* published a sketch of his life from the pen of its able editor, M. N. Forney, which contains so just and true an estimate of his worth and abilities, so keen an appreciation of the salient points of his character, that a liberal quotation from it seems most appropriate. Mr. Forney says:

"Mr. Fry had in a wonderful degree the capacity for investigating all subjects submitted for his judgment. With the most enduring patience and energy he would collect all the data relating to a subject, and, as it were, hold his mind in reserve until he had collected all the available material on which to form an opinion and base his conclusions. He was not a remarkably ingenious man, nor was he a very skillful designer of mechanism, but he had—what was perhaps much more valuable to

his employers—a judicial, mechanical mind. He would listen and give heed to both sides of a question, and weigh all the arguments for and against a given course, and then, cutting loose from tradition and prejudice and engineering cant—for there is such a thing—he would form his conclusions from the evidence before him. He was singularly without prejudice and pride of opinion, although he would urge his own views with great vigor when he thought that they were sustained by sound reasons and indubitable facts, and was tenacious of his own conclusions when he was convinced they were right.

"Of his own character, as known to those who were acquainted with him intimately, no one who knew him in such relations can write excepting with feelings of most tender affection. Among all those with whom he was acquainted he was respected, and there was a general feeling of the most implicit confidence in his integrity wherever he was known.

"But although there is so much that is inexpressibly sad in his death, he has left behind him an example of a noble career which is open to all. He was taken away on the very threshold of success, and before he had reaped the reward which the succeeding years of his life would have so certainly returned him. He accomplished what he did, in this country at least, without the personal influence of any one excepting those who were attracted to him by the certain indications of his ability, intelligence and integrity. It is no uncommon thing to hear young men lamenting that there is no career open to them, because they have none of that rather vague thing called 'influence.' In the life of Howard Fry we have an example of how a man, without any very great advantages of education or supereminent ability, coming a stranger into a new country where he was unknown, and by simply manifesting that he was true, honest and faithful, and that he knew how to perform his duties, can succeed so as to be honored, and can achieve what is worth much more than wealth. He was an example of a man who was willing to be poor in order that he might be honest, and those who are on the threshold of life may be certain that their integrity will not last long if there is not back of it the same readiness to forego the gratifications which wealth promises for the sake of retaining an entirely unblemished character."

His death was a severe shock to his many friends, and it was felt by each with a keen sense of personal loss. Quiet and unassuming as he was, he had a wonderful faculty of making friends and influencing for their good the character of all with whom he came in contact. He was only thirty-six years old at the time of his death, but a thick sprinkling of gray in hair and beard and a mature and thoughtful manner gave an impression of greater age.

In spite of his gray hair, however, Mr. Fry had an almost boyish freshness of feeling. He possessed to a high degree the English love of outdoor sports, and devoted his spare moments to tennis, archery, canoeing and fishing. As Mr. Forney says, "he was a man who was willing to be poor in order that he might be honest," and dying he left but small provision for his family. His friends, however, have formed a fund, now amounting to over $12,000, the income from which, it is hoped, will largely assist the stricken widow in educating her children.

I.

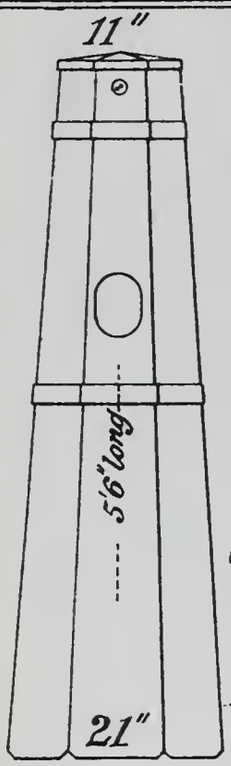
FIRE HYDRANTS.

By Frederic Graff, Member of the Club.

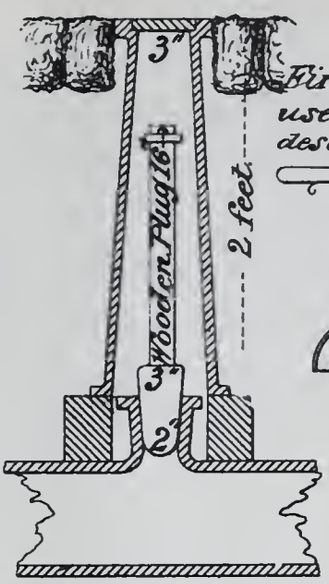
Read December 1st, 1883.

Some recent remarks made before the Club upon the subject of so-called "fire plugs" and the effect of frost upon the cases surrounding them, induces me to present a few facts relating to their early history, with extracts from books which will serve as comparisons with appliances used for similar purpose in England.

The title "fire plug," as applied to the fixtures in use in this country for supplying water in case of fire, is a misnomer which took its origin from the English "fire plug," a name which, it will be seen, is correct when employed to describe the appliance used there.

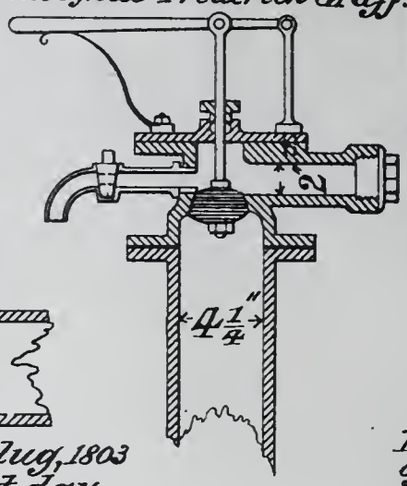


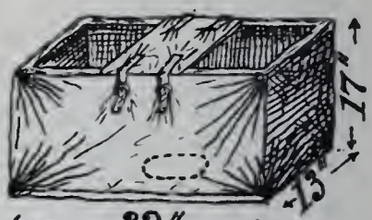
Wooden Case for fire Hydrants first used in Philad^{a}.



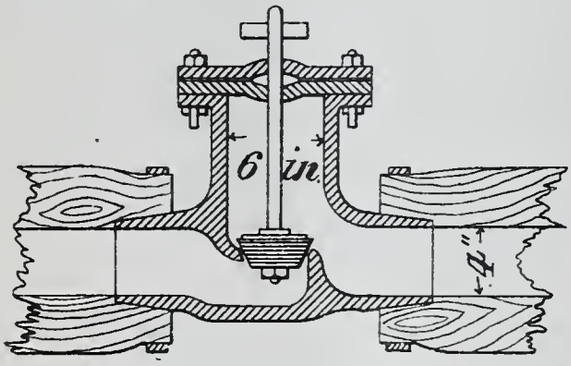
London fire-plug, 1803 to the present day.

Fireplug and Hydrant used in Philad^{a} in 1803, designed Frederick Graff.

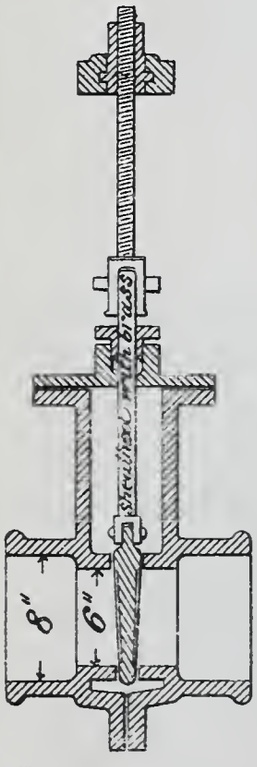


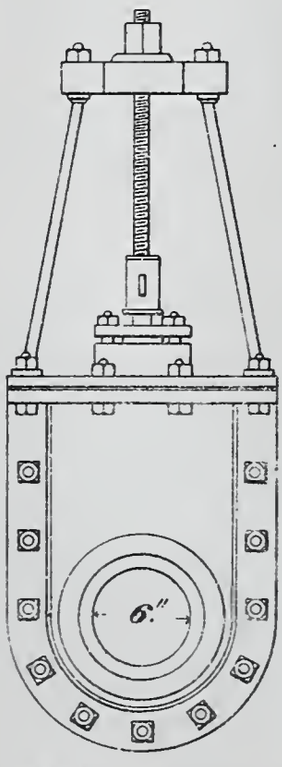


Sketch of portable dam made of canvas with jointed gas tubing frame; it is put over the plug opening, and kept down by stones or weights it folds flat, and is carried on the fire engine.

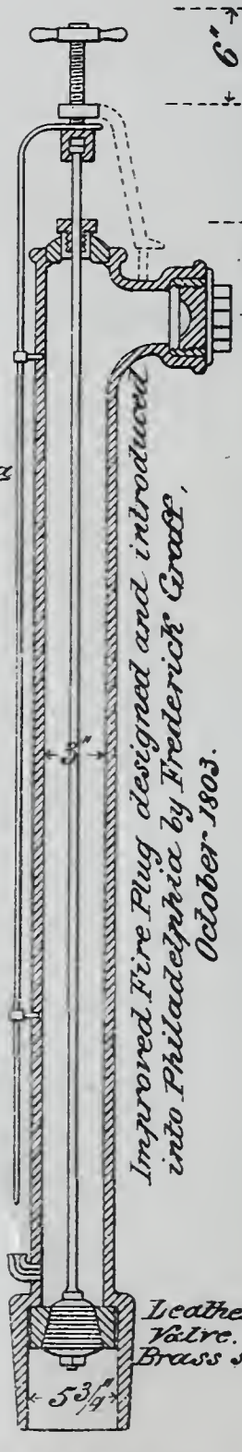


Stop used with wooden logs in Phil^{a} from 1801 to 1844.





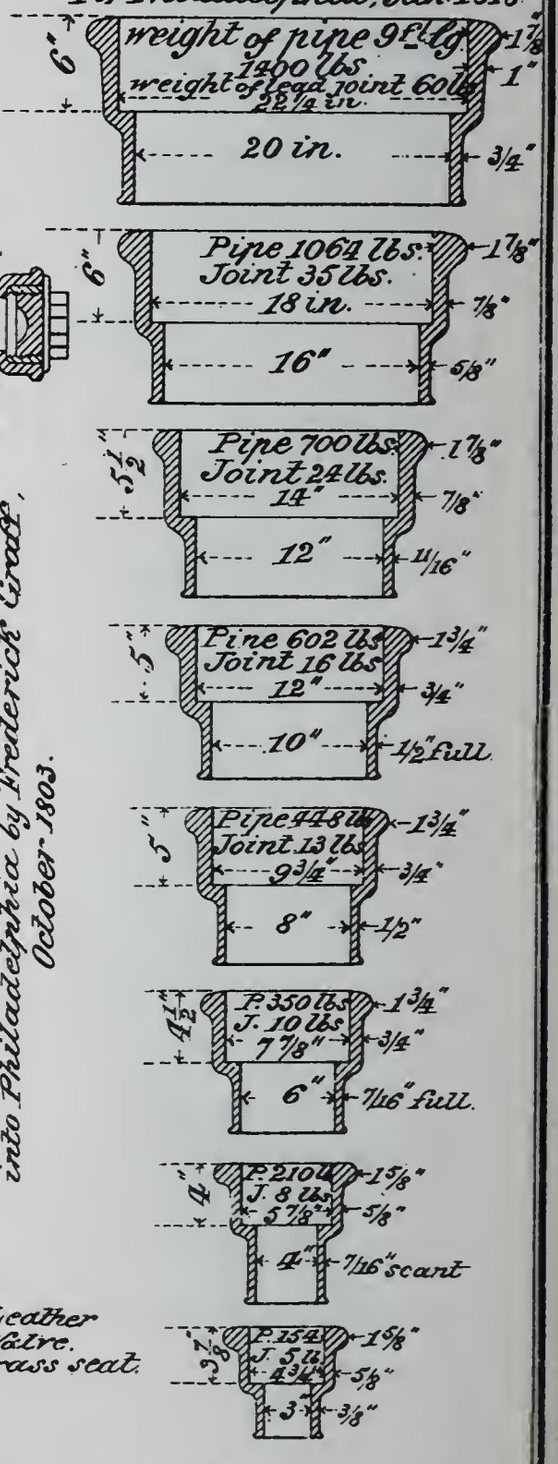
Double face Stop Cock, designed and introduced into Philadelphia by Frederick Graff in 1822.



Improved Fire Plug designed and introduced into Philadelphia by Frederick Graff, October 1803.

Leather Valve. Brass seat.

Proportion and weight of iron Pipes established by Frederick Graff for Philadelphia, Jan. 1818



In London and some other cities of England the supply of water is intermitting; the water pressure is not constantly on the street mains as with us.

The distribution is divided into districts; certain of these are supplied for an hour or two only each day, in some cases each alternate day, during which time the tenants have to collect in tanks, barrels or tubs, enough to supply their wants until the water is again turned on in their district.

The water is put on and off by individuals well known in London as the "turn cocks." When a fire occurs in any district where the water pressure is not on, it must burn until this very important officer can be found with his tools to turn on the supply. Of course this sometimes leads to much delay and consequent loss.

The following extract from a manual of the Fire Brigade of London, by Eyre M. Shaw, chief officer of the brigade, will give a clear description of the fire plug, and an account of the manner of using them, which forcibly exhibits the extraordinary tenacity with which the English people adhere to old customs and things.

Captain Shaw says: "The fire plugs consist, as their name expresses, of plugs or conical pieces of wood, which, when in use, are stuck into corresponding hollow iron sockets, cast on and forming part of the pipes, and these sockets communicate directly with the waterway inside.

"The socket is generally some two feet or so below the ground level, and the water is kept in simply by the conical plug being hammered tightly into the tapered opening, but without any other fastening whatever.

"The top of the wooden plug stands below the street level, and is protected from injury above by a small iron plate or paving-box, which either partially or completely covers the hole leading to the socket.

"The plug is also supposed to receive additional steadiness in its position and protection from frost by the hole being stuffed all around the head and up to the street level with horse litter or some such material, assumed to be a non-conductor; but unfortunately for this theory, it occasionally happens that not only the pipe and plug become frozen together into a compact and rigid

mass, but even under certain circumstances—as when water or damp has access into the hole—the filthy stuffing itself becomes congealed into a solid block of ice, with something like the consistency of flint, which, placed as it is underground, can turn the point of any crowbar, and can frequently withstand all efforts made to break through it until after the time has passed at which any advantage could be derived from obtaining access to the water."

We then have the following, to us in this country, amusing account of the method of using this very primitive fixture:

"In order to draw the plug it is necessary for the turncock, as a general rule, first to pick out the stuffing, and then insert an end of one of the tools, and to pinch the head of the plug to either side until the lower end or conical part becomes loose in the socket.

"Then if the pipe be charged under pressure the wooden plug will fly out; but if the pipe be not charged it is necessary to stick the pointed end of the tool known as the spoon into the top of the head, and by this means draw the plug within reach of the hand and so remove it, after which the sluice cock (the stop cock on the mains is so called in England) is opened to admit the water from the main."

A portable canvass cistern or dam with a hole in the bottom is placed over the plug case or opening, from which the water is "then pumped into an engine and out again through hose to wherever it is wanted."

"When the water is used with the pressure of the main only, a stand pipe is inserted, the lower end or shoe-piece fitting into the socket, and being secured by wedges driven in round it at the ground level or paving-box; a hose is attached to the stand pipe and the water is forced through it by the pressure due to the height of the reservoir or source."

These stand pipes are carried on the fire engine, and are of wrought-iron tube $2\frac{1}{2}$ inches diameter, with a gun metal shoe to drive into the outlets from which the wooden plug has been removed; the top is provided with a slide valve. Captain Shaw remarks as follows in regard to this stand pipe:

"A stand pipe, as here described, is a most imperfect imple-

ment; but it is the only one which can at present be made effectively available in London." This book was published in 1876.

The wooden fire plug described has been in use in London, without improvement, for from eighty to one hundred years. The accompanying sketch gives a section of it when shut and shows, also, the canvas dam.

From the first water-works of any size erected in this country (those of this city) to the present time, the supply has always been constant, and the rude fire plug of London would not answer; hence that now in use was designed.

It was at first so arranged that it could be used as a hydrant for the use of the public as well as for fire purposes, as shown in the sketch. This form had many disadvantages and was soon abandoned, and that so long in use, provided with a waste pipe and so-called frost rod, was substituted and designed by Frederick Graff, Sr. Although invented and put in use by him as early as 1802, its general principle and almost its mechanical construction have been universally adopted, in some form, in all the water-works since erected in this country.

The modifications are generally only such as have been brought about by the use of improved machinery and methods of construction, and the necessity of adapting the apparatus to the increased demand caused by the introduction of steam fire engines.

This made a larger size of the whole stand pipe and valve absolutely necessary, and the addition of a flange by which it could be securely attached to the goose neck or curved pipe leading from the mains, instead of by the lead joint previously used.

The original valve was made conical, fitting into a brass seat of corresponding form opening against the head of water, kept in place when shut by a screw handle and rod, as well as the pressure of water in the main, whereby the valve became tighter as the pressure increased.

I have never seen any radical departure from this form and principle of valve that has been so satisfactory. The valve was made of sole leather, soaked, pounded, cut into disks, screwed together on the bottom of the valve rod and turned in the lathe to the proper form.

These valves were exceedingly durable, and, unless accidentally injured, they have been known to keep in good repair, and shut perfectly tight, after having been in constant use for from ten to fifteen years.

Several cases came under notice of a similarly constructed valve of larger size, used as a stop valve, being in place forty-four years, useful, and shutting off perfectly tight to the last day.

The stops used upon the wooden logs first laid for the distribution of water to the city, were in form and principle much like the so-called "globe valve" of the present day. See sketch.

It is worthy of note that the foundry skill was so limited when these stops were first made that it was a very rare thing to find one of them (though they weighed but one to two hundred pounds) that did not contain numbers of blow holes through the casting, filled up with lead or solder.

The first double-faced valve for stop cocks on the street mains was invented and put in use by Frederick Graff, Sr., between the years 1819 and 1822, and is still in use, with very slight mechanical modifications, in all the water-works of this country.

The stops on the iron mains in London have, until a few years since, valves with a single face, kept up to its seat by wedges on the back.

The following extract is taken from the Autobiography of James Nasmyth, edited by S. Smiles, recently published. In the appendix he gives the account of his inventions, and, as will be seen by the following quotation, that gentleman re-invented the double-faced valve invented by Frederick Graff, Sr., eighteen or twenty years before and in use in all the works of the country for all that time.

"1839—The late Mr. Wickstead, engineer of the East London Water-Works, having stated to me the inconvenience which has been experienced from defects in respect of water tightness, as well as the difficulty of opening and closing the valves of the main water-pipes in the streets, I turned my attention to the subject. The result was my contrivance of a double-faced wedge shape sluice valve, which combined the desirable property of perfect water tightness with ease of opening and closing the valve; this was effected by a screw which raised the valve from

its bearings at the first partial turn of the screw, after which there was no great resistance or friction except the trifling friction of the screw and nut on the upper part of the sluice valve; when screwed down again it closed simultaneously the end of the entrance pipe and that of the exit pipe attached to the valve case in the most effective manner.

"Mr. Wickstead was so much pleased with the simplicity and efficiency of this valve that he applied it to all the main pipes of his company.

"When its advantages became known I received many orders from other water companies; the valves have come into general use.

"The prefixed figure will convey a clear idea of the construction.

"The wedge form of the double-faced valve is conspicuous as the characteristic feature of the arrangement."

This describes all the characteristics of the Philadelphia stop valve in use so many years before its re-invention by Mr. Nasmyth and its adoption by Mr. Wickstead, one of the most distinguished water-works engineers of England.

Our first fire hydrants were surrounded by a case made in octagon form, of cedar staves, one and a quarter inches thick, with a taper upon which iron hoops were driven. They were about eleven inches wide across squares at the top, twenty-one inches at bottom and five feet six inches long.

This form prevented the frost from raising them readily, the wood was a good non-conductor and left space for the hydrant and its branch, and could be packed with straw or other non-conducting material, which was the early practice.

Until about the year 1850 so-called "hydrant pumps" were considerably used in our city. A cistern or tub was sunk in the ground upon the foot walk, and was supplied with Schuylkill water through a ball cock and float; into this was placed an ordinary wooden pump. As this required labor to procure the water, the waste which would have occurred if public hydrants had been used was avoided.

They were very troublesome to keep in order, and reduced the revenue in some sections of the city very materially. They were gradually abandoned about the date above named.

The following extract from the minutes of the Institute of Civil Engineers of London upon the Water-Works of Edinburgh, Port Elizabeth, and Peterborough, May 22d, 1883, is a rather amusing confirmation of the fact that the double-faced stop valve invented by Frederick Graff was not known to English water-works engineers until the invention or re-invention of it by James Nasmyth. In the discussion of the above-named water-works, Mr. H. I. Martin says: "It has been stated in Mr. Gamble's paper that 'the sluice valves are of the usual pattern.' The usual patterns of the present day were in wonderful advance of those of thirty or forty years since. The great improvement originated with the introduction of 'the double-faced sluice cock.' This sluice cock, which had now superseded every other description, was the creation of Mr. James Nasmyth's inventive genius. Mr. Martin well remembered the first inception of this useful invention, as he happened—being at that time a pupil of the late Mr. Thomas Wickstead, M. Inst. C. E.—to have been present when Mr. Wickstead explained to Mr. Nasmyth the want he experienced of a sluice cock for water-works purposes that should shut and remain perfectly tight against a pressure coming from either side. Mr. Martin had a lively recollection of the instantaneous rapidity with which Mr. Nasmyth not only grasped, but provided for, the requirement, so that almost by the time Mr. Wickstead had completed the statement of his want, Mr. Nasmyth had drawn upon the back of an old letter a rough sketch of the first double-faced sluice cock, and in less than an hour had converted this rough sketch into a full-sized working drawing, in the preparation of which it fell to Mr. Martin's lot to have the honour to assist. In his autobiography Mr. Nasmyth referred to the conversation with Mr. Wickstead and introduced a print of the drawing made upon the occasion. The invention had been of the greatest use to the water-works engineer, especially in connection with the constant supply system, in which it frequently happened that the pressure was sometimes against one face of the sluice cock, and sometimes against the other."

II.

NOTES ON ENGLISH MACHINE TOOLS.

By Edward I. H. Howell, Member of the Club.

Read November 17th, 1883.

Many English machine tools have been imported during the past few years, and it will be of interest to examine into the construction of the average good tool of this type, as compared with American makes.

Lathes.

The same styles of lathes are made by nearly all English tool builders, the variations being mostly in swing and finish. There seems to be an accepted model for each size, which with a few modifications is followed by all builders. Thus for instance, all lathes, from the smallest foot lathe up to the heaviest tool, are built with a gap, or in the largest sizes, with a break in the bed. A lathe without a gap or break would with most makers be a special tool, and only built to order.

English shops prefer a combination tool, and will not buy two machines if one can be made to do the work.

Change gears, and gears generally, are cast, not cut; the makers insist that this method makes a stronger and better gear, and quite as accurate as if cut. Few American tool builders will believe this, however.

Hand wheels or handles on the apron of lathes for moving carriage or tool block, are always loose and with a long leverage, made necessary by the method of construction, which is calculated to develop the muscle of whoever runs the lathe.

The carriage is usually geared, so that the handle moving it must be turned away from the direction of motion.

A lengthy list of other peculiarities could readily be made if space permitted.

English lathes are all heavier than American makes, and this with the design, which in the smaller lathe is but a reduction in size of the larger tool, makes all up to about 40 inches swing look very clumsy.

The English tool builder seems to despise all adjustments for quick changes and rapid work, and constructs a machine in which time and muscle are important factors.

Small and medium-sized lathes of English make would be dear at any price in American shops, and the larger sizes would give satisfaction only on heavy work requiring little change, where a powerful tool at a low price is needed.

Drill Presses.

The universal use of the twist drill has developed the American tool to a very high degree of perfection, and nothing better is made than these small and medium-sized machines. In England however, the old flat drill still holds its place in the affections of the workman, and many of the smaller presses he uses would be considered obsolete in America.

In radial drills English builders offer a wide range of styles, some of the larger sizes being excellent tools, which could find a place in American shops where heavy work calls for a powerful machine.

Still, for general work, the best of the American tools would give in every instance greater satisfaction.

Planers.

English tools of this type approach nearer to the American designs than do either lathes or drills; the smaller sizes are, however, entirely unsuited for shops on this side of the Atlantic, being clumsy and awkward to handle; and the large tools (although more likely to please than either large drills or lathes) are not equal to American planers in quickness of adjustment and adaptability to various work.

Shapers.

English lists specify a range of sizes and styles greater than American shops think necessary to build; and although the smaller sizes of English shapers are clumsy, they still are good tools. The largest sizes are probably superior to anything turned out in America so far as weight and power are concerned, machines of 8 or 10 tons weight, and 24 inches stroke, not being uncommon.

Slotting Machines.

These are probably the only English tools of which all sizes could be used in American shops with good results. The variety of styles built in England is remarkable, and the best shops turn out excellent tools at very moderate prices.

Boring Mills

seem to be unknown in England, their place being poorly supplied by gap lathes, drill presses and horizontal boring machines.

Small Machine Tools.

In all tools such as are comprised in the large class of milling and screw machines, and in all other small tools used by machinists, England has nothing but the simplest and crudest forms.

However much the English manufacturer dislikes foreign machines, he is compelled to use American small tools (or their copies made in Germany). It seems to be impossible for an Englishman to copy exactly any machine; the result of all such efforts being usually a tool very different from the original and spoiled in the process.

The ideas of the English mechanic are reflected in the tools he builds. Conservative to a fault, and distrusting all novelties, he considers American tools as mere makeshifts.

The tools he builds must be solid, clumsy, and often out of all proportion to needed strength.

The English workman wishes a tool that looks as if it could not be easily moved, a piece of metal with "no nonsense about it;" when he takes hold of the handle to move the carriage of his lathe, he feels sure that there is a carriage there.

The influence of American ideas on the English tool builder is becoming more marked every year. Progressive Englishmen are coming to see the true value of the improvements introduced here, and at no distant day we may expect to see many tools from Great Britain which can be used with entire satisfaction in our shops.

III.

THE FASCINES AND MATTRESSES OF THE DELAWARE BREAKWATER HARBOR IMPROVEMENT.

By G. T. Gwilliam, Member of the Club.

Read November 17th, 1883.

I take the pleasure in sending to the Club, the following description and accompanying sketch of the method of making fascines and mattresses and sinking the latter, to form the sill of the foundation of the proposed work, for closing the "Gap" in the Delaware Breakwater Harbor. The manner of closing this gap was described in a paper to the Club by Mr. J. M. Stewart, February 17th, 1883.

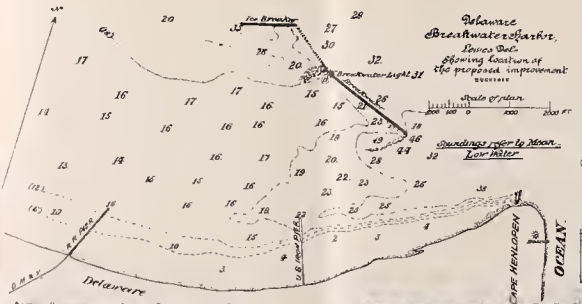
The object of this mattress foundation is to prevent the exceedingly strong current from scouring the bottom when the weight of the superstructure is put upon it and the filling begun.

The brush used consists of live willow, oak, gum, hickory, maple and chestnut saplings and branches, with butts from $\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter. It is made into fascines and grillage, being compressed on a rack by means of two levers and a chain, and tied with 1 inch sisal rope, the ties being about 4 feet apart.

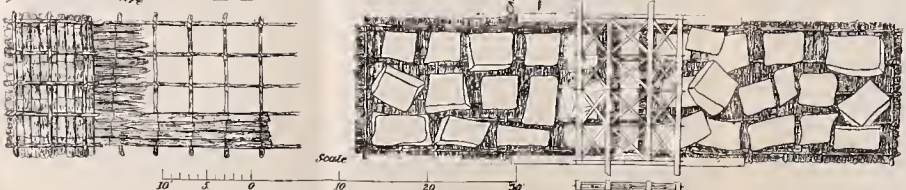
The fascines are made 8″ to 12″ in diameter, 16 feet long; the grillage is 3″ to 5″ in diameter, 16 and 35 feet long. The grillage is interwoven, making a network 16x30 feet, with some of the long parts protuding and forming "whip ends:" the fascines are then laid on lengthwise of the mat, with the feather ends lapping in the centre; then a layer of fascines constructed with butts at each end are laid crosswise; the top grillage is then put on, and the whole bound together.

It is secured at each cross of the grillage on the ends and sides and at every alternate cross in the middle with $1\frac{5}{8}$″ tarred ratline or Manilla rope, in one end of which an eye is spliced, and the other passed down through the mat, around the cross of the bottom grillage, up over the cross of the top and through the eye. It is then drawn tight with the rolling mallet. While the tie, which consists of two half hitches around the main part, is being made, the rope is held fast with a pair of tongs.

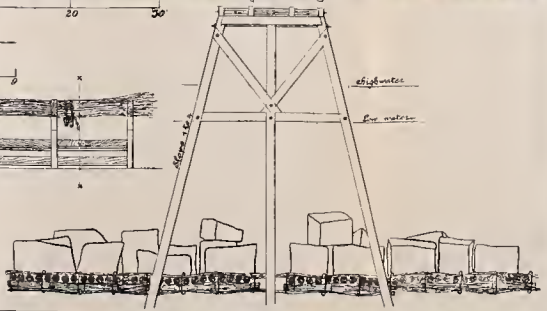
PROC. ENG. CLUB,
OF PHILAD'A.
Vol. IV, No. 1,
Plate III.



Rolling Mallet, Marline Spike & Tongs



Fascine Rack



Sketch of Mattresses used at the
Delaware Breakwater Harbor,
Showing details of construction
and Method of Sinking.

THE FASCINES A
BREAKWA

By G. T

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the foundation of th
the Delaware Breakv
gap was described ir
February 17th, 1883.

The object of this r
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of the superstructure

The brush used
maple and chestnut
$2\frac{1}{2}$ inches in diamet
being compressed on
and tied with 1 inch

The fascines are
the grillage is 3″ to
grillage is interwove
of the long parts pro
cines are then laid
ends lapping in the
with butts at each er
put on, and the who

It is secured at eac
and at every alterna
or Manilla rope, in
other passed down
bottom grillage, up
It is then drawn tig
which consists of tw
made, the rope is he

The mattresses are launched with skids and rollers and towed into position, two being lashed together by their whip ends, one on each side of the centre row of piles constituting the "bridge," and the outside ends, being made fast to guide buoys and scows, are loaded with stone from a lighter and sunk. The remaining piles are then driven and the superstructure built.

Among the difficulties to be overcome in driving the piles and sinking the mattresses, are the strong current of from 2 to 4 miles per hour, the great depth of water, which varies from 24 to 63 feet at low water, with an average of 40 feet, and the heavy seas which roll in during easterly weather.

IV.

THE SALINA TUNNEL.

By Samuel Rea, Member of the Club.

Read December 1st, 1883.

The improvement of the Western Pennsylvania Railroad (a leased line of the Pennsylvania Railroad, extending from Allegheny City to a connection with that road, fifty-three miles east of Pittsburgh), involving the reduction of its maximum grade from 52 feet to 21 feet per mile, was begun in the Spring of 1881 and completed in the Fall of 1883. Active work, however, was not inaugurated until late in the Fall of 1881.

The most important change was the construction of an entirely new line between Saltsburg and Roaring Run. The heaviest work encountered on the change was the Salina Tunnel, and a bridge over the Kiskiminetas River, near the eastern portal of the Tunnel: the former being illustrated in detail on the accompanying copy of original working plan.

The work was put under contract, dated December 22d, 1881, with Thomas Rutter & Co., of New York City, contractors, and John Brotherlin, Assistant Engineer, in charge of the division, which included ten miles of road, in addition to the tunnel and bridge.

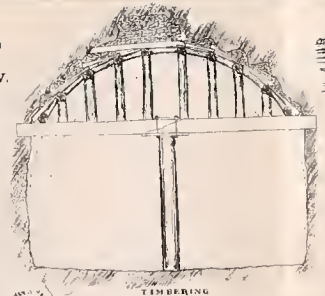
The manner of laying out the tunnel line and the necessary triangulations to secure the proper location of piers, abutments, etc., for bridge, is described on plan. Steel tapes were first used for measurement, but subsequently abandoned, and micrometer rods used instead, with very satisfactory results. Before doing any work under ground, the line was accurately established on the surface: first, by locating the ends of curve by measurement from the intersection of tangents, then by running curve in by chords of one hundred feet, and afterward by several long chords, until they were all made to agree, and finally securing the points so fixed with locust posts that reached below the frost line. We were then ready to commence running the centre line under ground, which had to be done in the same way as the line had been run by chords on the surface.

The axis of tunnel and the centre line of road on the tangent are identical, while on the curved portion the axis of tunnel is built one foot south of centre of road. The reason for this is obvious, since the track on curve had to be elevated for a speed of forty miles per hour, which would throw the cars over at top about one foot, necessitating this arrangement. The shift was made gradually at the rate of about six inches per hundred feet, approaching the curve from tangent.

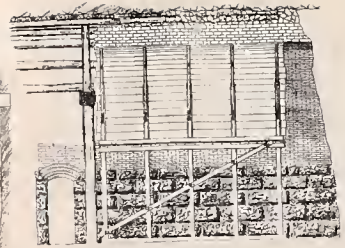
The contractors did not get under ground until April, 1882, at east end, and June, of same year, at west end. The profile of progress shows the work by months, as carried on until the headings met, which event occurred in March, 1883, at a point on the 6° curve, about 359+60. As soon as possible after the drifts met, the line was produced through the aperture, back-sight taken, the instrument reversed, when the cross-hairs struck within $\frac{5}{8}$ of an inch of centre of tack. The distance on first running checked within $\frac{15}{100}$ of a foot.

The tunnel section is 28 feet wide at springing line (which is probably the widest railroad tunnel in the world), and $20\frac{1}{2}$ feet above the rail at crown of arch. The side and façades are of first-class rock range masonry, while the arching in interior of tunnel is of brick, and composed of six half-brick rings, making a total depth of arch of about 26 inches. The arch-stones in façades are cut smooth and chamfered. The masonry at the

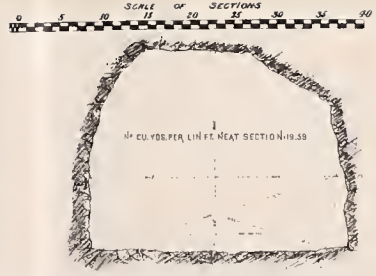
PROC. ENG. CLUB,
OF PHILA'A.
Vol. IV, No. 1, Plate IV.
REA—SALINA TUNNEL



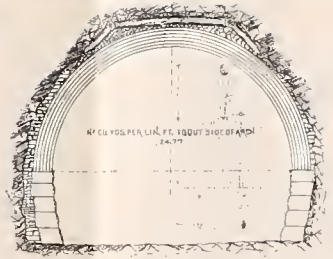
TIMBERING



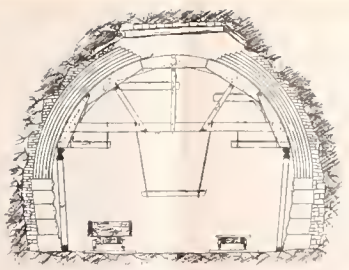
LONGITUDINAL SECTION
TIMBERING, CENTERING AND ARCHING



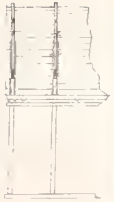
NEAT SECTION

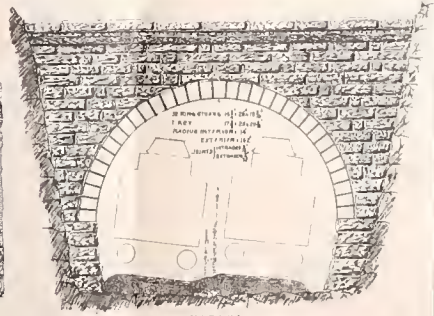


ARCHING, PACKING & SPUR BRACING



CENTERING

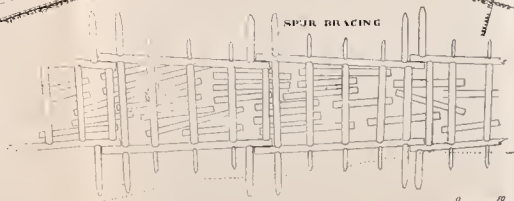


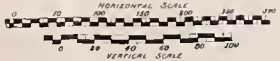


FACADE

PLAN SHOWING TUNNEL AS CONSTRUCTED

SPUR BRACING

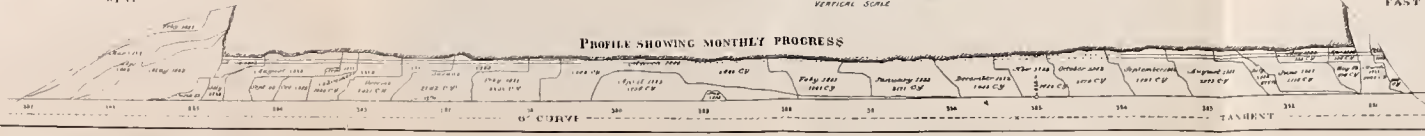




WEST

EAST

PROFILE SHOWING MONTHLY PROGRESS



CROSS SECTION

portals extends in from 5 to 10 feet, to a connection with the brick arching. Man-holes, as shown on longitudinal section of plan, were made every 200 feet, on alternate sides of tunnel.

The work of excavation was carried on night and day, in two shifts of ten hours each. Compressed air drills were employed at East end only; the character of rock at western end admitting of as rapid work with hand drills.

The systems of timbering, centreing, etc., employed during construction is clearly shown on plan.

The total length of tunnel between faces of keystone is 1,365.6 feet. About 815 feet of this length is arched, and the balance good rock tunnel. No spaces were allowed to remain over the arch or behind the side walls. Good masonry packing was used behind side walls and about half-way up on arches, and the balance packed with stone or brick.

The neat section contained 19.59 cubic yards per lineal foot, and the section to outside of arch, 24.77 cubic yards.

As a matter of record accurate cross-sections were taken every ten feet throughout the length of the tunnel, one being shown on the plan.

After the completion of the tunnel the north track only was laid. Good centre stones were set at point of curve, and every three hundred feet on the curve in the tunnel.

The work of cutting and setting the façades was very well done, one of the keystones not varying more than one-eighth of an inch from the plan.

The accompanying sketch gives a fair comparison of the alignment of the old and new lines on the tunnel division.

ANNUAL REPORT OF THE SECRETARY AND TREASURER,

For the Fiscal Year 1883.

Presented, January 12th, 1884.

To the Officers and Members of the Engineers' Club of Philadelphia:

Gentlemen:—I have the honor to present the following statement of the receipts and expenditures for the fiscal year from January 13th, 1883, to January 11th, 1884, inclusive.

Howard Murphy, Treasurer, in account with
The Engineers' Club of Philadelphia.

Dr.

Balance on hand Jan. 13th, 1883,		$ 51 55
Initiation fees,		220 00
Dues, 1880,		7 50
" 1882, Resident,	28 75	
" " Non-resident,	25 00	53 75
Dues, 1883, Resident,	1087 50	
" " Non-resident,	325 00	1412 50
Dues, 1884, Non-resident,	15 00	
" " Resident,	3 25	
" " amounts credited on account, Non-resident,	5 08	23 33
Subscription to Proceeding,		5 00
Sales of Proceedings, Authors,		2 31
" " Members,		12 82
" " Non-members,		14 00
Postage charged on Proceedings,		1 68
Advertisements, 1882,		225 00
" 1883,		183 00
Key deposits,		13 75
Sundry Receipts,		3 44
		$2229 63

Cr.

Rent to Jan. 1st, 1884,		650 00	
Gas,		27 60	
Janitor,		24 00	
Ice,		18 78	
Picture framing, supplies and repairs in rooms,		26 89	747 27
Salary of Secretary and Treasurer,			600 00
Proceedings, Vol. III, No. 3, balance,	138 82		
" " " " 4, "	250 02		
" " " " 5, on acc't,	4 50		
" " IV, " 1, "	1 50	394 84	
Lists of Members, Dec., 1882,	42 22		
" " " Oct., 1883,	45 70	87 92	
Printing and Stationery—Notices and Records,	146 35		
Printing and Stationery—Miscellaneous,	28 90	175 25	658 01
Postage,	143 60		
Expressage,	2 60		
Messengers,	1 61		
Telegrams,	69		147 90
Sundries,			4 32
Cash on hand January 11th, 1884,			72 13
			$2229 63

The following are the assets of the Club, in addition to its library and furniture.

Cash balance Jan. 11th, 1884,	$ 72 13
Due from members to date, initiation fees and dues, about*	222 50
Due for advertisements, about	300 00
Due for Proceedings, etc.,	31 14
Total assets, in addition to property, less current bills unpaid,	$625 77

* It is not possible always to determine whether Members are resident or non-resident, according to the rule, until they are heard from.

This includes the amount due for advertisements in that number of the Proceedings which is now in press, and is, together with one or two small unsettled accounts, to be paid for from these assets. Our net balance, therefore, would be about $400.

My last Report showed the assets of the Club, in addition to its library and furniture, to be $491.55, less current bills unpaid. The current bills, at that time, were quite large, as Vol. III, No. 3 of the Proceedings, an edition of the List of Members, etc., had not been settled for. The actual net balance of last year was but about $265.

While the overlapping of the business of the Club from year to year makes an accurate analysis of the accounts, by separate years, impossible, the above showing is quite correct, and when we consider the facts that this increase of balance has been created by no practice of any economy that interfered with our doing all that we undertook to do in the best manner, by no increase of dues, and in spite of the reduction of several of the items of revenue of last year, we have reason to congratulate ourselves upon our financial status. The real secret of our continued success is, as I have always maintained, our continued increase in membership. I am more convinced than ever that *a large membership upon small dues* is our true theory. The number of candidates for Active Membership before this very meeting is good evidence of our prospective growth, so I will not reiterate further upon this subject than to say, "*keep it up.*"

As your Corresponding and Recording Secretary I have the honor to present the following Report for our Sixth Fiscal Year.

MEETINGS.

Regular, ...	14
Business, ...	2
Special Business, ...	2
Total, ...	18

ATTENDANCE.

Members, total, ...	394
" average, ...	22—
(" " 1882, . 22+)	
Visitors, total, ...	37
(" " 1882, . . . 33)	

The Board of Directors have held five meetings for the transaction of their usual business.

Continuing the Membership Table from my last Report (Vol. III, No. 4, p. 258), we have the following result:

	HON.	COR.	ACT.
Membership at end of fiscal year 1882, .	4	8	204
Additions, ...			43
Transferred from Corresponding to Active,		1	1
		7	248
Deceased, ...	1	1	1
	3	6	247
Resignations, etc., ...			3
	3	6	244

The net increase of Active Membership has therefore been $19\frac{6}{10}$ per cent:

Upon the extraordinary loss the Club has sustained by death I will not comment, as touching Memorials have already been presented to you, except to note the remarkable fact that from each of our classes of members *one* has been taken and, in each case, one of the most remarkable men in his class.

The following original papers have been presented to the Club during the past year.

A Machine for the Graphical Determination of Centre of Gravity and Moment of Inertia of Plane Areas, by Wilfred Lewis.

Delaware Breakwater Harbor Improvement, by J. M. Stewart.

The Steamship "Mariposa," by Horace See.

A New Method of Estimating the Contents of Highly Plicated Coal Beds as Applied to the Anthracite Fields of Penn'a, by C. A. Ashburner.

Method of Receiving Bids and Letting Contracts for Iron Bridges on the P., McK. and Y. R. R., by P. F. Brendlinger.

A Graphical Method of Earthwork Calculation, by Edw. Thiange.

Economy in Highway Bridges, by Prof. J. A. L. Waddell.

Tides and Newton's Theory of Them, by E. A. Gieseler.

The Effect of Frost upon Fire Plug Casings, by A. J. Fuller. Discussion by Frederic Graff, Prof. L. M. Haupt and Howard Murphy.

Notes on English Machine Tools, by Edw. I. H. Howell.

The Mattresses and Fascines of the Delaware Breakwater Harbor Improvement, by G. T. Gwilliam.

Fire Hydrants, by Frederic Graff.

Notes on Injectors, by S. L. Kneass.

The Salina Tunnel, by Samuel Rea.

Notes on Clamping Bolts, by Wilfred Lewis.

The following contribution have been made to the Club Reference Book:

A Graphic Solution of Cubic Equations, by Prof. M. Merriman.

Table of Bolts, Nuts and Threads, by W. P. Osler.

Formulæ for Railroad Turnouts and Crossings, by John Marston.

Reduction Tables, by Howard Murphy.

Tables for Stadia Reduction, by Arthur Winslow.

Electrical Units of Work and Power Corresponding to all Mechanical Units, by C. O. Hering.

Conventional Colors for Drawings, by Prof. L. M. Haupt.

Streets, Roads and Pavements, by C. H. Haswell.

Methods of Computing Tables, by J. J. Hoopes.

The following Notes and Communications have been presented:

Express Locomotive, by Geo. S. Strong.

Shaw Locomotive, by Wm. E. Lockwood (Visitor).

Improved Averaging Machine, by W. S. Auchincloss.

Metallic Packing for Piston Rods, etc., by J. J. de Kinder.

The Loiseau Artificial Fuel, by Dr. H. M. Chance.

Device for Plumbing Transit Pole and Shelf for Field Instruments, by C. E. Chandler (Correspondent).

A Process for Drying Wood, by C. René (Correspondent).

Phosphor Bronze for Measuring Tapes, by John T. Boyd.

Cable for Electric Wires, by C. O. Hering.

Illustrations of Very Tough and Homogeneous Cast Steel, by Percival Roberts, Jr.

The Southern Pacific R. R. in California, by T. M. Cleemann.

A Location on the Western N. Carolina R. R., by T. M. Cleemann.

Corrugated Tubes, by Geo. S. Strong.

Artificial Fuels, by E. F. Loiseau.

Cable and Bucket Derricks, by R. H. Sanders and T. M. Cleemann.

Impurities in Reservoirs, by C. G. Darrach.

Illustrations of Railroad Location (B. and O. R. R.), by C. G. Darrach.

The Panama Canal, by Col. Jas. Worrall.

The Black Rock Tunnel Bridge, P. and R. R. R., by Prof. L. M. Haupt.

Japanese Papers, by Prof. J. A. L. Waddell.

Lift Bridge over Oswego Canal, N. Y., W. S. and B. R. R., by Jno. A. Partridge (correspondent).

Specimens of Marine Architecture, by John Haug.

Early Mining Operation in Berks and Chester Cos., and the Jones Mine, by J. H. Harden.

Copper Mining in the Northwest, by P. C. F. West.

Notes on Clepsydræ, by Prof. L. M. Haupt.

Notes on Boiler Construction, by John Haug.

Cylindrical and Corrugated Flues, by Geo. S. Strong.

Dust Explosions in Mills, by C. J. Hexamer. Discussion by W. A. Ingham and T. Mellon Rogers.

Locomotive Cross-head and Guide, by F. W. Dean (Visitor).

Horse Shoe Manufacture at Bryden Forge Co's. Works, Catasauqua, Pa., by Washington Jones.

New Press for Manufacture of Paving Blocks from Asphalt and Crushed Rock, by E. F. Loiseau.

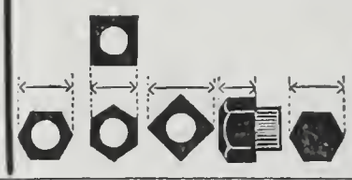
Single Seat, Balance Steam and Water Relief Puppet Valve, by Washington Jones.

Respectfully submitted,

HOWARD MURPHY, *Secretary and Treasurer.*

BOLT HEADS, NUTS AND THREADS.

Wm. P. Osler, March 3d, 1883.

Diameter.	No. Threads per Inch.	Diameter at Bottom of Thread.	Area at Bottom of Thread.	Tensile Strain at 12,000 lbs. per Square Inch. ¼ of Brk. Weight.	Shearing Strain of a Full Bolt at 9,500 lbs. ¼ of Brk. Weight.	Nuts.		Heads.		Washers.		
												Gauge.
										A	B	
¼	20	.185	·027	324	465	$\frac{27}{64}$	$\frac{1}{2}$	$\frac{45}{64}$	$\frac{1}{4}$	$\frac{27}{64}$	$\frac{5}{8}$	$\frac{5}{16}$ 16
$\frac{5}{16}$	18	.240	.045	540	728	$\frac{11}{16}$	$\frac{19}{32}$	$\frac{54}{64}$	$\frac{19}{64}$	$\frac{1}{3}\frac{7}{2}$	$\frac{3}{4}$	$\frac{3}{8}$ 16
⅜	16	.294	.068	814	1045	$\frac{51}{64}$	$\frac{11}{16}$	$\frac{63}{64}$	$\frac{11}{32}$	$\frac{5}{8}$	1	$\frac{7}{16}$ 14
$\frac{7}{16}$	14	.344	.093	1116	1425	$\frac{29}{32}$	$\frac{25}{32}$	$1\frac{7}{64}$	$\frac{25}{64}$	$\frac{7}{16}$	$1\frac{1}{4}$	$\frac{1}{2}$ 14
½	13	.400	.125	1500	1864	1	$\frac{7}{8}$	$1\frac{15}{16}$	$\frac{7}{16}$	$\frac{27}{32}$	$1\frac{3}{8}$	$\frac{9}{16}$ 12
$\frac{9}{16}$	12	.454	.161	1942	2702	$1\frac{1}{8}$	$\frac{31}{32}$	$1\frac{23}{64}$	$\frac{31}{64}$	$\frac{31}{32}$	$1\frac{1}{2}$	$\frac{5}{8}$ 12
⅝	11	.507	.201	2422	2914	$1\frac{7}{32}$	$1\frac{1}{16}$	$1\frac{1}{2}$	$\frac{17}{32}$	$1\frac{1}{16}$	$1\frac{3}{4}$	$\frac{11}{16}$ 10
¾	10	.620	.302	3622	4197	$1\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{49}{64}$	$\frac{5}{8}$	$1\frac{9}{32}$	2	$\frac{13}{16}$ 10
⅞	9	.731	.420	5048	5712	$1\frac{23}{32}$	$1\frac{7}{16}$	$2\frac{1}{32}$	$\frac{23}{32}$	$1\frac{15}{32}$	$2\frac{1}{4}$	$\frac{15}{16}$ 9
1	8	.837	.550	6600	7461	$1\frac{7}{8}$	$1\frac{5}{8}$	$2\frac{1}{64}$	$1\frac{1}{16}$	$1\frac{23}{32}$	$2\frac{1}{2}$	$1\frac{1}{16}$ 9
$1\frac{1}{8}$	7	.940	.694	8327	9453	$2\frac{3}{32}$	$1\frac{13}{16}$	$2\frac{9}{16}$	$\frac{29}{32}$	$1\frac{29}{32}$	$2\frac{3}{4}$	$1\frac{1}{4}$ 9
$1\frac{1}{4}$	7	1.065	.890	10680	11666	$2\frac{5}{16}$	2	$2\frac{53}{64}$	1	$2\frac{1}{8}$	3	$1\frac{3}{8}$ 9
$1\frac{3}{8}$	6	1.160	1.056	12672	14088	$2\frac{17}{32}$	$2\frac{3}{16}$	$3\frac{3}{32}$	$1\frac{3}{32}$	$2\frac{7}{32}$	$3\frac{1}{2}$	$1\frac{1}{2}$ 9
$1\frac{1}{2}$	6	1.284	1.294	15528	16786	$2\frac{3}{4}$	$2\frac{3}{8}$	$3\frac{23}{64}$	$1\frac{3}{16}$	$2\frac{9}{16}$	$3\frac{3}{4}$	$1\frac{5}{8}$ 8
$1\frac{5}{8}$	$5\frac{1}{2}$	1.389	1.515	18180	19702	$2\frac{31}{32}$	$2\frac{9}{16}$	$3\frac{5}{8}$	$1\frac{9}{32}$	$2\frac{3}{4}$	$3\frac{7}{8}$	$1\frac{3}{4}$ 8
$1\frac{3}{4}$	5	1.491	1.745	20040	22852	$3\frac{3}{16}$	$2\frac{3}{4}$	$3\frac{57}{64}$	$1\frac{3}{8}$	$2\frac{31}{32}$	4	$1\frac{7}{8}$ 8
$1\frac{7}{8}$	5	1.616	2.051	24612	26229	$3\frac{1}{32}$	$2\frac{15}{16}$	$4\frac{5}{32}$	$1\frac{15}{32}$	$3\frac{3}{16}$	$4\frac{1}{4}$	2 8
2	$4\frac{1}{2}$	1.712	2.302	27624	29845	$3\frac{5}{8}$	$3\frac{1}{8}$	$4\frac{27}{64}$	$1\frac{9}{16}$	$3\frac{7}{32}$	$4\frac{1}{2}$	$2\frac{1}{8}$ 8
$2\frac{1}{4}$	$4\frac{1}{2}$	1.962	3.023	36276	37779	$4\frac{1}{16}$	$3\frac{1}{2}$	$4\frac{61}{64}$	$1\frac{3}{4}$	$3\frac{23}{32}$		
$2\frac{1}{2}$	4	2.176	3.718	44616	46616	$4\frac{1}{2}$	$3\frac{7}{8}$	$5\frac{31}{64}$	$1\frac{15}{16}$	$4\frac{1}{4}$		
$2\frac{3}{4}$	4	2.426	4.622	55464	56426	$4\frac{29}{32}$	$4\frac{1}{4}$	6	$2\frac{1}{8}$	$4\frac{11}{16}$		
3	$3\frac{1}{2}$	2.629	5.428	65136	67151	$5\frac{3}{8}$	$4\frac{3}{8}$	$6\frac{17}{32}$	$2\frac{5}{16}$	$5\frac{1}{8}$		
$3\frac{1}{4}$	$3\frac{1}{2}$	2.879	6.499	77988	78802	$5\frac{13}{16}$	5	$7\frac{1}{16}$	$2\frac{1}{2}$	$5\frac{13}{32}$		
$3\frac{1}{2}$	$3\frac{1}{4}$	3.100	7.547	90564	91399	$6\frac{7}{64}$	$5\frac{3}{8}$	$7\frac{39}{64}$	$2\frac{1}{16}$	$5\frac{33}{32}$		
$3\frac{3}{4}$	3	3.317	8.640	103690	104927	$6\frac{21}{32}$	$5\frac{3}{4}$	$8\frac{1}{8}$	$2\frac{7}{8}$	$6\frac{3}{8}$		
4	3	3.567	9.992	119904	119377	$7\frac{3}{32}$	$6\frac{1}{8}$	$8\frac{41}{64}$	$3\frac{1}{16}$	$6\frac{13}{16}$		
$4\frac{1}{4}$	$2\frac{7}{8}$	3.798	11.327	135931	134767	$7\frac{9}{16}$	$6\frac{1}{2}$	$9\frac{3}{16}$	$3\frac{1}{4}$	$7\frac{1}{8}$		
$4\frac{1}{2}$	$2\frac{3}{4}$	4.028	12.743	152904	151088	$7\frac{31}{32}$	$6\frac{7}{8}$	$9\frac{3}{4}$	$3\frac{7}{16}$	$7\frac{31}{32}$		
$4\frac{3}{4}$	$2\frac{5}{8}$	4.256	14.225	171704	168534	$8\frac{13}{32}$	$7\frac{1}{4}$	$10\frac{1}{4}$	$3\frac{5}{8}$	$8\frac{3}{32}$		
5	$2\frac{1}{2}$	4.480	15.763	189154	186632	$8\frac{23}{32}$	$7\frac{5}{8}$	$10\frac{49}{64}$	$3\frac{13}{16}$	$8\frac{1}{2}$		
$5\frac{1}{4}$	$2\frac{1}{2}$	4.730	17.571	210852	205656	$9\frac{9}{32}$	8	$11\frac{23}{64}$	4	$8\frac{15}{16}$		
$5\frac{1}{2}$	$2\frac{3}{8}$	4.953	19.267	231204	225691	$9\frac{23}{32}$	$8\frac{3}{8}$	$11\frac{7}{8}$	$4\frac{3}{16}$	$9\frac{3}{8}$		
$5\frac{3}{4}$	$2\frac{3}{8}$	5.203	21.261	255132	246696	$10\frac{5}{32}$	$8\frac{3}{4}$	$12\frac{3}{8}$	$4\frac{3}{8}$	$9\frac{25}{32}$		
6	2	5.423	23 097	277164	268613	$10\frac{19}{32}$	$9\frac{1}{8}$	$12\frac{15}{16}$	$4\frac{9}{16}$	$10\frac{7}{32}$		

GRAPHIC SOLUTION OF CUBIC EQUATIONS.

Prof. Mansfield Merriman, March 3d, 1883.

The following is a convenient method for obtaining approximate values of the roots of cubic equations.

1st.—Plot on a sheet of cross section paper a curve of cubes (or the curve whose equation is $y = x^3$), taking the numbers as abscissas and their cubes as ordinates. By the help of a table of cubes this curve may be rapidly and accurately drawn, and if of sufficient extent it will serve for the solution of all numerical cubic equations.

2d.—Reduce the given equation to the form $x^3 + ax = b$.

3d.—Lay off on the axis of ordinates a distance equal to b, and on the axis of abscissas a distance equal to $\frac{b}{a}$, taking care to observe the signs of a and b.

4th.—Draw a straight line to join the points thus determined, and if necessary produce it to intersect the curve.

5th.—If the line intersects the curve in only one point, the abscissa of the point of intersection will be the real root of the equation, and the other two roots will be imaginary. If the line intersects the curve in three points, the abscissas of the three points of intersection will be the three real roots of the equation.

The accompanying figure shows the curve of cubes laid off for abscissas from -4 to $+4$ and ordinates from -64 to $+64$, the vertical scale being one-tenth of the horizontal.

It also shows, by way of example, the solution of the equation $x^3 + 12x = +30$. First on the vertical axis a point is marked at $+30$, then on the horizontal axis a point is marked at $+2.5$ (or $+\frac{30}{12}$), and these two points are joined by a straight line. The line cuts the curve at a point whose abscissa is $+1.9$, which is an approximate value of the root of the given equation, the other two roots being imaginary.

Usually it will be unnecessary to draw the straight line and mark the abscissa as shown in the figure, but a ruler may be laid down joining the two points on the axes, and its intersection with the curve noted.

If b is negative it must be laid off downward from the origin instead of upward, and if $\frac{b}{a}$ is negative it must be laid off to the left of the origin instead of to the right. The following may serve as examples:

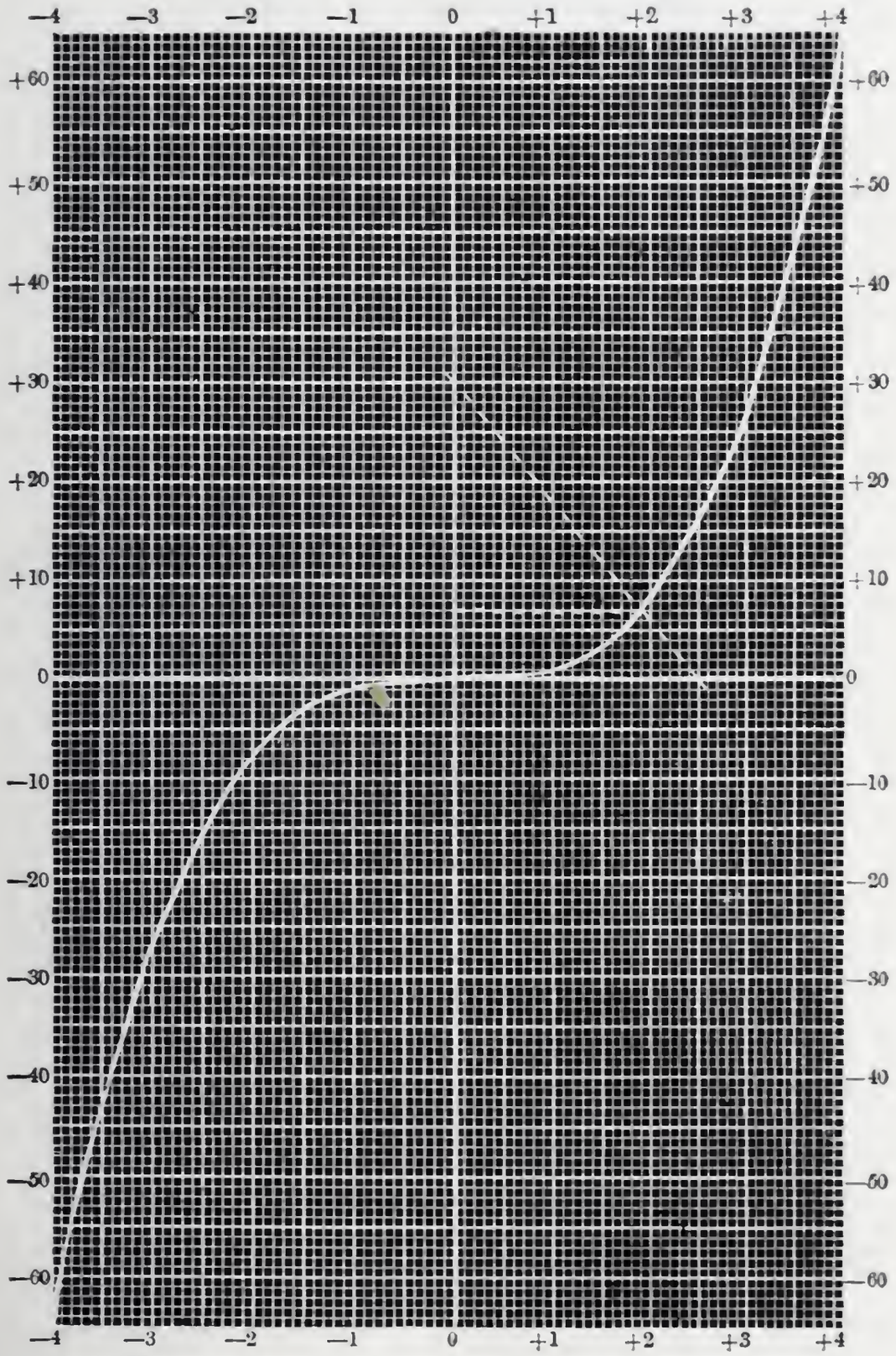
For $x^3 + 20x = +30$, we find $x = +1.4$ and two imaginary roots.

For $x^3 + 20x = -30$, we find $x = -1.4$ and two imaginary roots.

For $x^3 - 20x = -30$, we find $x = +1.8$, $x = +3.3$ and $x = -5.1$.

For $x^3 - 20x = +30$, we find $x = -1.8$, $x = -3.3$ and $x = +5.1$.

The truth of the above process may be readily seen by considering that the abscissa of the intersection of the curve $y = x^3$ with the straight line $y = -ax + b$ must be a root of the equation $x^3 = -ax + b$, or of the equation $x^3 + ax = b$. Evidently the same method may be used for the solution of any numerical equation of the form $x^n + ax = b$.



Graphic Solution of Cubic Equations—Page C.

VULGAR FRACTIONS OF 1 INCH REDUCED TO EXACT DECIMALS OF 1 INCH.

HOWARD MURPHY, April 5th, 1884

$\frac{1}{64}$	.015625	$\frac{17}{64}$	.265625	$\frac{33}{64}$	.515625	$\frac{49}{64}$	.765625
$\frac{1}{32}$	.03125	$\frac{9}{32}$	.28125	$\frac{17}{32}$	.53125	$\frac{25}{32}$	.78125
$\frac{3}{64}$	.046875	$\frac{19}{64}$	.296875	$\frac{35}{64}$	.546875	$\frac{51}{64}$	.796875
$\frac{1}{16}$	.0625	$\frac{5}{16}$	.3125	$\frac{9}{16}$	.5625	$\frac{13}{16}$	.8125
$\frac{5}{64}$	.078125	$\frac{21}{64}$	.328125	$\frac{37}{64}$	.578125	$\frac{53}{64}$	.828125
$\frac{3}{32}$	.09375	$\frac{11}{32}$	.34375	$\frac{19}{32}$	.59375	$\frac{27}{32}$	.84375
$\frac{7}{64}$	.109375	$\frac{23}{64}$	.359375	$\frac{39}{64}$	.609375	$\frac{55}{64}$	.859375
$\frac{1}{8}$	.125	$\frac{3}{8}$	.375	$\frac{5}{8}$	.625	$\frac{7}{8}$	.875
$\frac{9}{64}$	.140625	$\frac{25}{64}$	.390625	$\frac{41}{64}$	640625	$\frac{57}{64}$	.890625
$\frac{5}{32}$	.15625	$\frac{13}{32}$	.40625	$\frac{21}{32}$	.65625	$\frac{29}{32}$	.90625
$\frac{11}{64}$	.171875	$\frac{27}{64}$	.421875	$\frac{43}{64}$	.671875	$\frac{59}{64}$	.921875
$\frac{3}{16}$	.1875	$\frac{7}{16}$	.4375	$\frac{11}{16}$	.6875	$\frac{15}{16}$	.9375
$\frac{13}{64}$	.203125	$\frac{29}{64}$	.453125	$\frac{45}{64}$	.703125	$\frac{61}{64}$	.953125
$\frac{7}{32}$	.21875	$\frac{15}{32}$	.46875	$\frac{23}{32}$	.718750	$\frac{31}{32}$	.96875
$\frac{15}{64}$	.234375	$\frac{31}{64}$	.484375	$\frac{47}{64}$	.734375	$\frac{63}{64}$	.984375
$\frac{1}{4}$	.25	$\frac{1}{2}$	.5	$\frac{3}{4}$	.75	1	1.

COMPUTATION OF TABLES.

J. J. HOOPES, Nov. 17th, 1883.

In order to avoid a repetition of the same calculations, tables of functions are given for quantities or elements differing by a constant difference.

The object of these notes is to illustrate methods of computing various tables by successive additions, instead of making a separate calculation for each function. This may not always be the shortest method, but it has the advantage that if any one of the results obtained is checked and found correct, the results preceding it must also be correct.

Where there is a fixed ratio between the given and the required quantities, a constant difference in the one will

produce a constant difference in the other, and the table may be formed by successive additions of this latter difference. Thus, in a table of miles and feet,

1 mile = 5280 feet or 1 foot = 0.000189394 miles
2 miles = 10560 " or 2 feet = 0.000378788 "
3 " = 15840 " or 3 " = 0.000568182 "

We have 5280 feet to add for each additional mile, or 0.000189394 miles for each additional foot.

In a table of Board Measure for 1 foot long and 1 inch thick, for various widths, we have for

$\frac{1}{4}''$ wide, .02083̇ ft. B.M.
$\frac{1}{2}''$ " .04166̇ " "
$\frac{3}{4}''$ " .06250 " "
$1''$ " .08333̇ " "

and .02083̇ ft. B.M. for each additional $\frac{1}{4}''$ width. For $1\frac{1}{4}''$, $1\frac{1}{2}''$, $1\frac{3}{4}''$, etc., thick, the quantities, and also the common difference, will be $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, etc., times as great as for $1''$ thick.

Where the functions are proportional to the squares of the quantities upon which they depend, they may also be obtained by successive additions, for, although the difference between successive squares is not a constant, the difference between the differences is a constant.

Nos.	Difference.	Squares.
0		0
1	1	1
2	3	4
3	5	9
4	7	16
5	9	25
6	11	36

Thus, in a series of squares, we find the differences between the squares have a common difference of 2, and hence the series could be continued by making each succeeding difference greater by 2 than the preceding difference, and each square found by adding the corresponding difference to the preceding square.

AREAS OF TRIANGLES WITH BASES $1\frac{1}{2}$ TIMES THE PERPENDICULARS.

Perpendiculars differing by 0.1 ft.			Perpendiculars differing by 0.2 ft.		
Perps.	Diffs.	Areas.	Perps.	Diffs.	Areas.
0.0		.0000	0.0		0.00
0.1	.0075	.0075	0.2	0.03	0.03
0.2	.0225	.0300	0.4	0.09	0.12
0.3	.0375	.0675	0.6	0.15	0.27
0.4	.0525	.1200	0.8	0.21	0.48
0.5	.0675	.1875	1.0	0.27	0.75

In the first of these tables the difference between the differences is .0150 and in the second it is .06.

In tables for level cuttings the same method may be employed. Thus, for a 30 ft. road bed and 1 to 1 slopes:

Height.	Difference.	Content of Prisms of 100 length in c. yds.
0.0		0.000
0.1	11.$\dot{1}4\dot{8}$	11.$\dot{1}4\dot{8}$
0.2	11.$\dot{2}2\dot{2}$	22.$3\dot{7}0$
0.3	11.$\dot{2}9\dot{6}$	33.$6\dot{6}\dot{6}$
0.4	11.$3\dot{7}0$	45.$0\dot{3}\dot{7}$
0.5	11.$\dot{4}4\dot{4}$	56.$4\dot{8}1$

Here the differences between successive contents have a common difference of .$0\dot{7}\dot{4}$.

As the areas of circles are proportional to the squares of their diameters, the same method may be employed in computing a table of these areas.

Where the functions are cubes, or proportional to the cubes, of the given quantities, the same general method may be employed in computing a table of these functions, but another order of difference is introduced. Thus from a series of cubes, by deducing the various orders of difference, we have:

Nos.	2d Order of Differences.	1st Order of Differences.	Cubes.
0			0
1		1	1
2	6	7	8
3	12	19	27
4	18	37	64
5	24	61	125
6	30	91	216

Here we find the 2d order of differences have a common difference of 6, and hence, to continue the series, add 6 to the preceding number in the 2d order of difference, add this sum to the preceding number in the 1st order of difference, and add this sum to the preceding cube.

In a series of the 4th powers of consecutive numbers we find one more order of difference than the cubes, and an ultimate common difference of 24.

Nos.	3d Order of Differences.	2d Order of Differences.	1st Order of Differences.	4th Power.
0				0
1			1	1
2		14	15	16
3	36	50	65	81
4	60	110	175	256
5	84	194	369	625
6	108	302	671	1296

In like manner the same method could be employed for higher powers.

What tables it would be best to compute by this method, as well as what tables it is worth while to compute at all, is a matter for individual judgment. The advantage already named for this method will probably commend it in many cases, even where the labor involved is greater than by other methods.

ABSTRACT OF MINUTES OF MEETINGS.

Of the Club.

January 12th, 1884.—Sixth Annual and Business Meeting.—President Henry G. Morris in the chair. Fifty-two members and nine visitors present, being the largest attendance at any meeting to date.

The Retiring President, Mr. Henry G. Morris, delivered the Annual Address.

The Secretary and Treasurer presented his Annual Report.

Mr. Edward I. H. Howell very acceptably occupied the time required to finish the counting of the votes by a description, illustrated by samples, of the manufacture of Cold Drawn and Polished Shafting.

The Tellers of Election, Messrs. Codman and Beardsley, announced that one hundred and thirty votes had been polled, and the following Officers elected for the year 1884: President, Col. William Ludlow; Vice-President, J. J. de Kinder; Secretary and Treasurer, Howard Murphy; Directors, T. M. Cleemann, Frederic Graff, Rudolph Hering, Washington Jones and Henry G. Morris.

Col. Ludlow then took the chair for 1884, with appropriate remarks.

The Tellers also announced that the following Amendment to Article VII of the Constitution had been passed by a vote of 174 to 14, 163 votes being the requisite two-thirds of the entire Active Membership. At the end of third line to strike out the word "*Annual*" and insert in place thereof the words "NEXT BUSINESS," and in the seventh line to strike out the words "*agreed to by two-thirds of the Members*" and insert in place thereof the words "FAVORED BY TWO-THIRDS OF THE VOTES CAST."

So that the Article shall read:

"Amendements to this Constitution shall be presented in writing at a Business Meeting, signed by at least five Members: they may be amended and shall then be laid over until the *next business* meeting, in the notices for which meeting it shall be set forth that "an Amendement to the Constitution" (giving the wording of such

proposed amendement) "will be acted upon," and if it shall then be *favored by two-thirds of the votes cast* by letter ballot, it shall be adopted."

The Annual Meeting adjourned and the Business Meeting was called to order. The Secretary reported from the Board of Directors of last year that they had held a final meeting, approved outstanding bills and adjourned *sine die.*

The following gentlemen were reported by the Tellers as having been elected Active Members of the Club: Messrs. Coleman Sellers, E. A. Wilson, Geo. M. Evans, Frank Maddock, T. E. Austin, Henry J. Hartley, D. E. Pierce, Frederic Rosenberg, Alfred B. Stovell, Geo. V. Cresson, Harvey Linton, William Ingles, John C. Trautwine, Jr., C. Henry Ott, H. W. Hand and B. Frank Richardson.

The resignations from Active Membership of Messrs. E. A. Gieseler and W. E. Partridge were read and accepted.

January 19th, 1884.—Regular Meeting.—President William Ludlow in the chair. Twenty members and three visitors present.

After calling the meeting to order, President Ludlow said:

"I deeply regret, gentlemen, that almost my first official duty, as your President, is to appear as a harbinger of ill tidings, and to announce to you the death of our Past President, Mr. Strickland Kneass; a man whom you all knew, and knowing, held in the highest esteem—a typical good citizen and good engineer, faithful in every relation of life, full of industry and conscientiousness, devoted to duty, warm-hearted, clear-headed, capable and honorable.

A special meeting of the Board was held on Thursday, for the consideration of the best method by which our appreciation of Mr. Kneass, and our deep regret at his loss, might be expressed for transmission to his friends and incorporation into the records of the Club.

It was thought fitting to substitute for the drafting of the ordinary resolutions, which bear, perhaps unavoidably, a somewhat perfunctory character, the preparation of a Memorial, containing such a recital of the history of Mr. Kneass as should more effectively set forth his distinguished services and example, both to the professon and to the community.

The Special Committee to whom this duty is assigned consists of Messrs. Graff, Chairman, DuBarry, Worrall, McClure and Dye, the gentlemen best qualified to discharge it."

Mr. Wilfred Lewis read a paper upon the "Resilience of Steel," reviewing some of the means employed for the storage of energy, and showing the place occupied by steel among them.

Mr H. C. Lüders presented a description, illustrated by photographs, of the ancient ship found near Sandefjord, in Norway.

He also exhibited specimen of Rolled and Annealed Phosphor-bronze of maximum ductility, and consequently of minimum tensile strength, and submitted the following data of the test thereof: length, 2″; diameter, 0.57″; subjected to a strain of 13,620 lbs., equivalent to 53,400 lbs. per square inch; elongation, 70.5 per cent.; reduced area at point where fracture would occur, 0.3″; elastic limit, about 18,000 lbs. per square inch. Hard rolled rods tested without turning off the surface, have shown a tenacity exceeding 90,000 lbs. per square inch.

The Secretary presented, for Mr. Louis C. Madeira, Jr., the Record of American and Foreign Shipping, containing an interesting set of drawings for the details of construction of iron ships.

Mr. Percival Roberts, Jr., gave some account of the results of experiments, now being conducted by Mr. James Christie, at Pencoyd, upon the relative elasticity of iron and steel structural shapes.

February 2d, 1884.—Regular Meeting.—President William Ludlow in the chair. Forty-four members and nine visitors present.

Mr. William Lorenz presented a comprehensive discussion of Steel and Iron Railroad Ties, illustrated by numerous full-sized models and drawings.

Mr. C. J. Quetil, introduced by Mr. J. J. de Kinder, gave an illustrated description of his Wire Truss Railway.

President Wm. Ludlow exhibited specimens of Obstructed Water Pipe, discovered in his practice, and explained the chemical causes which led thereto.

Mr. J. Milton Titlow exhibited and described a full set of general and detail drawings for the proposed stone bridge over

the Schuylkill River at Market Street, Philadelphia. As the cost thereof is estimated at $1,200,000, in the discussion which followed, President Ludlow suggested the alternative of building two $600,000 iron bridges therewith—one at Market Street and one at Walnut Street, over the Schuylkill, the latter bridge being very greatly needed at this time.

Mr. E. F. Loiseau presented a description of the process of manufacture of Portland Cement by the application of his solidifying apparatus.

Mr. Robt. W. Lesley, visitor, supplemented Mr. Loiseau by explaining the difference between the old and the above-mentioned methods in actual practice.

February 16th, 1884.—Regular Meeting.—Vice-President J. J. de Kinder in the chair. Forty-three members and six visitors present.

Mr. Chas. A. Ashburner detailed his experience in the use of Aneroids in Leveling. He exhibited a collection of various forms of instruments and described their advantages and errors, and the means of correcting the latter, the graphical method being specially recommended.

The Secretary presented, from Mr. Edwin Ludlow, a description of the Exhaust Injector, with results of experiments therewith.

The Secretary presented, from Prof. J. A. L. Waddell, an illustrated paper upon Lateral Systems for Iron Pratt Truss Highway Bridges.

Of the Board of Directors.

January 12th, 1884.—Special Meeting.—President Henry G. Morris in the chair. Five members present. Bills approved, $2267.61. The Board of Directors for 1883 then adjourned *sine die*.

January 17th, 1884.—Special Meeting, called for the purpose of taking action upon the death of Past President Strickland Kneass.

Vice-President J. J. de Kinder in the chair. Four members present.

It was thought best that no resolutions should be passed, but

that the President should make formal announcement of the death of Mr. Kneass at the next meeting of the Club, and that a Committee should be appointed to prepare a Memorial for publication in the Proceedings. The following Committee was appointed for that purpose: Messrs. Frederic Graff, Chairman, Jos. N. DuBarry, James Worrall, Jas. R. McClure and John H. Dye.

February 29th, 1884.—Special Meeting held, by the courtesy of the President, at his residence, No. 2215 St. James Place, Phila.; —the full Board present.

The President announced the following Standing Committees of the Board for 1884: Finance, Messrs. Frederic Graff and Henry G. Morris; Membership, Messrs. Henry G. Morris and J. J. de Kinder; Publication, Messrs. T. M. Cleemann and Washington Jones; Library, Messrs. Rudolph Hering and T. M. Cleemann.

The accounts of the Treasurer were, at his request, referred to the Finance Committee for audit.

The Secretary presented a statement of the finances of the Club, and the question of taking enlarged quarters was discussed, and a Committee, consisting of President Ludlow and Messrs. Graff and Morris, was appointed to inquire into and report upon the new house project.

The Secretary announced the contribution to the Library of a large number of books, documents and maps by General Wm. F. Raynolds, and the thanks of the Board were returned therefor. The price to members of extra copies of Club phototype portraits was fixed at 5 cents each. The price of Reference Book sheets was referred to the Committee on Publication. Author's price, for extra copies of Proceeding prior to Vol. III, No. 2, was fixed at 10 cents per copy.

CONTRIBUTIONS TO THE LIBRARY.

FROM DECEMBER 2D, 1883 TO FEBRUARY 29TH, 1884.

The Club specially and gratefully acknowledges the kind and acceptable contribution, by GENERAL WM. F. RAYNOLDS, of *a library in itself*, consisting of hundreds of Scientific Reports and Documents, Pamphlets and Maps; and the deposit in the Rooms of six framed Photographic Views of Bridges, by MR. JOSEPH S. SMITH, Member of the Club.

From the INSTITUTION OF CIVIL ENGINEERS, London, England.
Appleby—Experiments in Iron and Steel.
Thomson—Electrical Units of Measurement.
Bruce—The Northern Pacific Railroad.
Coghlan—Discharge of Streams in Relation to Rainfall, New South Wales.
Durand—Spontaneous Combustion in Collieries.
Address of Sir J. W. Bazalgette, C.B., President. Jan. 8th, 1884.
Annual Report of the Council—Dec. 18th, 1883.
Abstracts of Papers in Foreign Transactions and Periodicals. Vol. LXXIV. Session 1882-83. Part IV.

From the NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, Newcastle-upon-Tyne.
Transactions—Oct., Dec., 1883.

From the SOCIETY OF CIVIL ENGINEERS, Paris.
Mémoires—Oct. and Nov., 1883.

From L'ADMINISTRATION DES PONTS ET CHAUSSÉES, Paris.
Annales—Aug., Oct., Nov., Dec., 1883.

From the AUSTRIAN SOCIETY OF ENGINEERS AND ARCHITECTS, Vienna.
Wochenschrift.
Zeitschrift—Parts V and VI, 1883.

From the VEREIN FÜR BAUKUNDE, Stuttgart, Germany.
Proceedings—Oct., Dec., 1883.

From the NORWEGIAN ASSOCIATION OF ENGINEERS AND ARCHITECTS, Kristiania.
Norsk Teknisk Tidsskrift—I, 4 and 5-6, 1883.

From the SWEDISH SOCIETY OF CIVIL ENGINEERS, Stockholm.
Proceedings—Tredje Häftet, 1883.

From the PORTUGESE SOCIETY OF CIVIL ENGINEERS, Lisbon.
Proceedings—Sept., Oct., 1883.

From the ARGENTINE SCIENTIFIC SOCIETY, Buenos Aires.
Anales—Nov., Dec., 1883; Jan., 1884.
Sistema de Medidas y Pesas de la República Argentina. 1881.

From the GEOLOGICAL AND NATURAL HISTORY SURVEY of Canada.
Report of Progress with Maps—1880-81-82.

From the AMERICAN SOCIETY OF CIVIL ENGINEERS, New York.
Transactions—Sep., Oct., Nov., 1883.

From the AMERICAN IRON AND STEEL ASSOCIATION, Phila.
The Bulletin.

From the AMERICAN SOCIETY OF MECHANICAL ENGINEERS, New York.
Transactions—Vol. IV. 1883.
Officers, Members and Rules—Jan. 1st, 1884.

From the UNITED STATES ASSOCIATION OF CHARCOAL IRON WORKERS, Philada.
Journal—Dec., 1883; Feb., 1884.
Index to Vol. IV. 1883.

From the AMERICAN SHIPMASTERS' ASSOCIATION, New York.
Record of Foreign and American Shipping—No. 2. 1884.

From the ASSOCIATION OF ENGINEERING SOCIETIES, New York.
Journal—June, July—Aug. and Sept.—Oct., 1883.

From the ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.
Transactions.

From the SCHOOL OF MINES, Columbia College, New York.
Quarterly—Nov., 1883.

From the AMERICAN PHILOSOPHICAL SOCIETY, Philadelphia.

Proceedings—April, 1883, to Jan. 4th, 1884.

From the PHILADELPHIA SOCIAL SCIENCE ASSOCIATION.

Blodget—The Social Condition of the Industrial Classes of Philadelphia. 1883.

Garrett—Progress of Industrial Education. 1883.

13th An. Rep. for 1883.

From the FRANKLIN INSTITUTE, Philada.

Journal—Jan., Feb., 1883.

From the LIBRARY COMPANY OF PHILADELPHIA.

Bulletin—Jan., 1883.

From the UNITED STATES COAST AND GEODETIC SURVEY, Washington, D. C.

Report. 1882 Bound.

From the UNITED STATES GEOLOGICAL SURVEY, Washington, D. C.

1st An. Rep. 1880. Bound.

2d An. Rep. 1880-81. Bound.

Dutton—Tertiary History of the Grand Canon District. Text and Atlas. 1882. Bound.

Bulletin—No. 1. 1883.

From the COMMISSIONER OF RAILROADS, U. S. A., Washington, D. C.

Annual Report for year ending June 30th, 1883. Bound.

From the SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

Reports—AC, C^4, D^3 Vol. I, D^3 Vol. II Part I, I^4 and G^7.

Atlases—AA, AC, D^3 Vols. I and II, and D^5.

From the HARBOR BOARD, Baltimore, Md.

An. Rep. for 1883.

From the BOARD OF HEALTH, Philada.

Extracts from Report—Drainage, Streets, Water Supply, etc. 1883.

From the Author, PROF. H. CARVILL LEWIS, Philadelphia.

A Summary of Progress in Mineralogy. 1884.

From MR. HARRY BIRKINBINE, Ch. Engr., Member of the Club.

Council Bluffs, Ia., Water-Works—Five Photographic Views.

From MAJ. H. W. CLARKE, Member of the Club.

Manual of Board of Supervisors, Onondaga Co., N. Y. 1883-4.

Journal of do. for 1883.

Proc. Bd. of City Auditors, Syracuse, N. Y., for 1883.

From the Author, MR. THOS. M. CLEEMANN, Member of the Club.

Cleemann—Railroad Engineer's Practice. 1884. Bound.

From MR. LOUIS C. MADEIRA, JR., Member of the Club.

Record of American and Foreign Shipping—Jan. 1st, 1884. Bound.

ADDITION TO EXCHANGE LIST.

PROGRESSIVE AGE and WATER GAS JOURNAL, Philada.

LIST OF MEMBERS.

ACTIVE.

Additions, January 12th, 1884.

Sellers, Coleman, Mech. Engr., 1600 Hamilton St., Phila.
Wilson, E. A., Asst. Engr., Kentucky Central Ry.,
Luray, Page Co., Va.
Evans, Geo. M., Engr. and Contractor, Roanoke, Roanoke Co., Va.
Maddock, Frank, Engr., Roanoke Land and Imp. Co.,
Roanoke, Roanoke Co., Va.
Austin, T. Everett, Mech. Engr., with Geo. S. Strong,
1222 Mt. Vernon St., Phila.
Hartley, Henry J., Supt. Smithey and Boiler Dept., Port Richmond Iron Wks., 1057 Richmond St., Phila.
Pierce, Dwight E., President Lloyd Valve Co., S. Bethlehem, Pa.
Rosenberg, Frederic, Asst. Supervisor P. R. R., Spruce Creek, Pa.
Stovell, Alfred B., Mech. Engr., 3101 Chestnut St., Phila.
Cresson, Geo. V., Machinist and Manufacturer,
S. E. Cor. 18th and Hamilton Sts., Phila.
Linton, Harvey, Asst. Engr., Phila. Water Dept.,
925 Walnut St., Phila.
Ingles, William, Asst. Engr., N. and W. R. R.,
Roanoke, Roanoke Co., Va.
Trautwine, John C., Jr., Civil Engineer., 530 N. 6th St., Phila.
Ott, C. Henry, Asst. Engr., Phila. Survey Dept.,
1107 Chestnut St., Phila.
Hand, H. W., Mech. Engr., I. P. Morris Co.,
1057 Richmond St., Phila.
Richardson, B. Frank, Engr., Balt. and Ohio R. R.,
1604 South Eleventh St., Phila.

Resignations.

Gieseler, E. A.
Partridge, W. E.

Deceased.

Kneass, Strickland, Past President, January 14th, 1884.

BOOK NOTICES.

EVOLUTION. G. P. Putnam's Sons. New York.

This little book of 44 pages, being a lecture delivered in Montreal, by Mr. Robert C. Adams, is a very readable and popular statement of the most modern theory of creation, with the evidence by which it is supported. As was to be expected, it is in the nature of special pleading, and the author does not always give the opposite side of his case. In treating of the nebular hypothesis, it seems to us that he should have stated that it was something more than that a vaporous matter by rotation threw off rings, etc. The most important point in this hypothesis, by which La Place deduced analytically Kepler's empirical laws, which he thus established on a basis of reason as well as observation, is, that besides the impulsive rotating force, there also exists the force of gravitation, by virtue of which all bodies attract each other directly as their masses, and inversely as the square of the distance. It is perfectly possible to conceive of some other universe, in which masses attracted each other as the cube of the distance, and, if our analytical accomplishments were sufficient, we could deduce the laws of motion, which would differ from those of Kepler. The existence of the law seems to imply the existence of a Lawgiver.

However satisfactory the explanation of the successive development of species, yet to most minds it is difficult, even after accepting it as true, to likewise accept the spontaneous generation of the first organic cell. There seems to be an absolute difference in kind between the symmetrical and permanent arrangement of atoms in a crystal, and the ephemeral arrangement in life.

Many, too, find it difficult to understand, though they owe it, perhaps, to their own ignorance, why a study of the rocks should reveal so many "cataclysms," which seemed to destroy most of the life of the period, and which were immediately followed by a crowd of different species, without any evidence of the intervening links. Future study, it is true, may reveal the location of these remains, but does this seem probable to the living geologist?

THE TOURISTS' GUIDE BOOK TO THE UNITED STATES AND CANADA. G. P. Putnam's Sons. New York.

Those persons who have been able to enjoy the advantages of Baedeker's European Guide Books, often wish that that enterprising publisher would visit our own country, and give us as valuable a handbook for our own use. Several publishers have tried to issue one on his model, and that mentioned above is the latest candidate for public favor; yet what a long interval exists between them. Baedeker's books treat of the detail that travelers especially want to know. The cost of the hotels, the amount of the gratuities expected by porters and guides, the *savoir faire* of traveling, often save the petty annoyances which otherwise spoil the pleasure of an interesting locality. Baedeker, too, gives large scale maps, by which a pedestrian is rendered independent of local guides, and can see all points of interest for himself without questioning any one. He would have had maps of Mt. Desert and Watkin's Glen, and would have noted with a star the fine views to be obtained from Newport Mountain in the former, and the hill overlooking the lake at the latter. West Point and the Catskills would likewise have had special maps. In these regards the Guide Books of Osgood & Co. are much superior.

In little things the book wants revising by natives of the places spoken of. For instance, in Philadelphia, the traveler from New York does not see the grounds of the Centennial Exhibition on his left as he enters the city. If he takes the Ridge Avenue cars to go to the Zoological Gardens, he will never get there. Girard bequeathed his estate to the City and not to the State. The library of the Historical Society is in their fine building, at Thirteenth and Locust Streets, which is itself a historical building. Mr. Claghorn and Mr. Rothermel would not like to see their names spelled Cleghorn and Rotherwel, and we may add that some Americans will be annoyed at seeing the name of Gen. Washington's wife spelled Curtis, in the article on the City of Washington.

Most persons will wonder how Patrick Henry could have made his celebrated speeches in Carpenter's Hall, in 1774, if it was not built until 1790.

In the Philadelphia churches, too, the one that has the finest monuments of the dead in the country—the sculptures of Steinhauser—is not even mentioned, though it likewise has one of the finest choirs.

We may add that the University Club, of Philadelphia, was worthy of mention, and above all that the Engineers' Club deserved a prominent place, which only its modesty prevents it from asserting.

SUPPLY PIPE TO 1716 18 20 22 & 24 CATHARINE ST
PHILADELPHIA, PA.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17th, 1877.

NOTE.—The Club, as a body, is not responsible for the facts and opinions advanced in its publications.

Vol. IV.] MAY, 1884. [No. 2.

V.

CHEMICAL OBSTRUCTIONS IN IRON WATER PIPES.

By COL. WM. LUDLOW, President of the Club.

Read February 2d, 1884.

THE accompanying illustration is of a specimen of water pipe, which had been recently taken up for the improvement of the water supply to certain dwellings. The specimen, about twelve inches long, is of two inch pipe, which had been in the ground for twelve or fourteen years, connecting the main in the street with the house fixtures. The occupant of the premises complained of an insufficient supply.

Upon testing the water pressures with a guage, it was found that the hydrant in front of the house had a pressure of seventeen pounds, which was reduced in the kitchen of the house to seven pounds, the difference clearly indicating an obstruction in the service pipe.

The owner was requested to take up the pipe and renew it.

The piece of the old pipe having been sawed longitudinally, the interior was found to be nearly filled with a deposit composed of the sesquioxide of iron and sedimentary matters, the tortuous channel through the pipe being constricted at several points to about three-eighths of an inch.

Another piece of obstructed pipe (originally three inch) exhibited had been in the ground over thirty years, and become almost entirely closed from the same cause.

The pipe lay in the ground in the rear of three houses on Fifteenth Street below Pine, for which it had constituted the sole source of supply.

Discoveries of this kind are constantly being made, and pipe that has been in the ground over ten or twelve years cannot be depended upon to convey its full volume.

Two methods of obviating this difficulty other than galvanizing, which was not considered advisable for a supply of water for drinking purposes, were known.

The one in use by the Department for its larger mains, namely, coating the pipe, when newly made, with a coal tar pitch prepared and applied in accordance with certain specifications, apparently protected the pipe for a period of from twenty-five to thirty years. This, however, would be less advantageous in the case of small service pipes, for the reason that it decreased in a considerable proportion the available diameter.

The other method was a process known as the "Bower Barff," which consisted in coating the pipe with a film of magnetic oxide, produced by subjecting the iron to the action of superheated steam, or air under certain conditions.

This process promised good results, but was not in full operation at this time.

Prof. Haupt suggested another process which had been patented by Mr. Gill, which likewise had the effect of covering the pipe with a film of black oxide.

VI.

DIAGRAMS FOR SIMPLE AND COMPOUND RAILROAD EARTHWORK FORMATIONS.

By Edward Thiange and J. M. Rüdiger, Jr., Members of the Club.

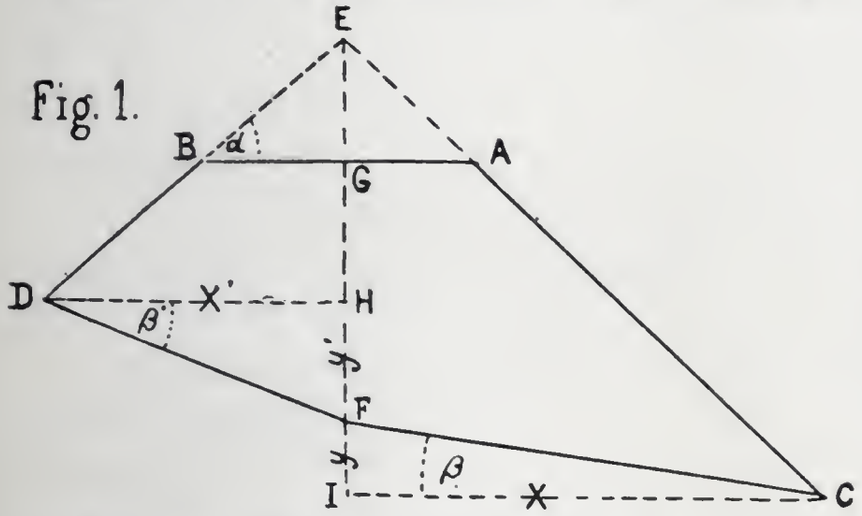
Read October 6th, 1883.

SECTION I.

Formulæ for Simple Formations.

Fig. 1, *ABDFG*, represents an embankment; AB = roadway; $GF = h$ = centre height; α = slope angle of formation; β and β' = slope angles of the ground; $EG = h'$, $CI = X$, $HD = X'$, $FI = y$, $HF = y'$, areas $ECF = A$, $EFD = A'$ and $AEB = a$, called grade area. Then is $CABDF = A + A' - a$. But $A = \frac{1}{2}(h+h')X$ and $A' = \frac{1}{2}(h + h')X'$.

Fig. 1.



But since

$$X = (h + h' + y) \text{ cotang } \alpha$$

and $$y = X \text{ tang } \beta$$

then is $$X = \frac{h + h'}{\text{tang } \alpha - \text{tang } \beta}$$

In the same manner

$$X' = (h + h' - y') \text{ cotang } \alpha$$

and $$y' = X' \text{ tang } \beta'$$

then is $$X' = \frac{(h + h')}{\text{tang } \alpha + \text{tang } \beta'}$$

and substituting, we get

$$A = \frac{(h + h')^2}{2(\text{tang } \alpha - \text{tang } \beta)} \text{ and } A' = \frac{(h + h')^2}{2(\text{tang } \alpha + \text{tang } \beta')}$$

Since $h' = \frac{1}{2} r \text{ tang } \alpha$ then is $a = \frac{1}{4} r^2 \text{ tang } \alpha$,

$$\therefore \text{area } CABDF = \frac{(h + h')^2}{2(\text{tang } \alpha - \text{tang } \beta)} + \frac{(h + h')^2}{2(\text{tang } \alpha + \text{tang } \beta'} - \tfrac{1}{4} r^2 \text{ tang } \alpha.$$

In this formula h', r and α are constant for each formation.

When the section is level on both sides, β and β' are nothing and the formula reduces to

$$\frac{(h+h')^2}{\text{tang } \alpha} - \tfrac{1}{4} r^2 \text{ tang } \alpha.$$

In applying the formulæ observe the following rule: In embankments take the slope angles of the ground with their proper signs, in excavations with their opposite signs, as excavation is but an inverted embankment.

Compound Sections.

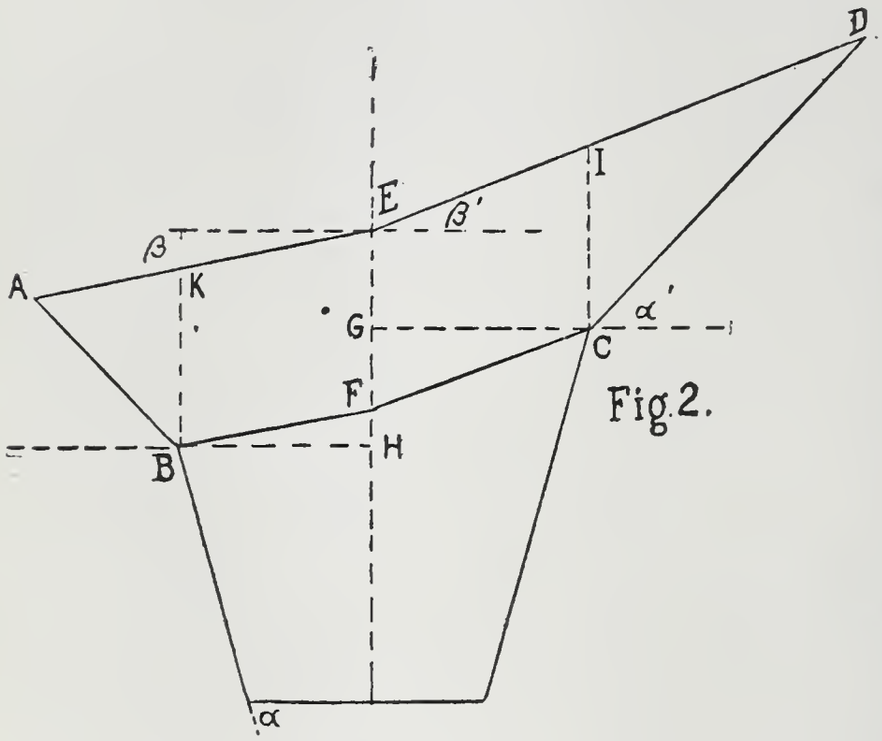


Fig. 2.

In the case of compound sections of rock and earth, as in Fig. 2, the area of the rock can be obtained directly by the formulæ just given, observing the rule regarding the slope angles.

The earth section is equal to the area of the triangles *ABK*, *DCI* and the parallelograms *KBFE* and *ICFE*. Now $IC = KB =$ depth of earth, hence *ABK* and *DCI* can be obtained by the formula,

$$A_0 = \frac{(EF)^2}{2\,(\text{tang } \alpha' - \text{tang } \beta')} + \frac{(EF)^2}{2\,(\text{tang } \alpha' + \text{tang } \beta)}$$

The sum of the areas of the two parallelograms is equal to the product of

$$EF \times (BH+GC),\ BH+GC = \frac{h''+h'}{\text{tang } \alpha + \text{tang } \beta} + \frac{h''+h'}{\text{tang } \alpha - \text{tang } \beta'}$$

where $h'' =$ height of rock and h' the constant height of grade triangle.

Since $\dfrac{1}{\text{tang } \alpha + \text{tang } \beta}$ and $\dfrac{1}{\text{tang } \alpha - \text{tang } \beta'}$, for different values of α and β, are given in the tables, these areas can be quickly calculated.

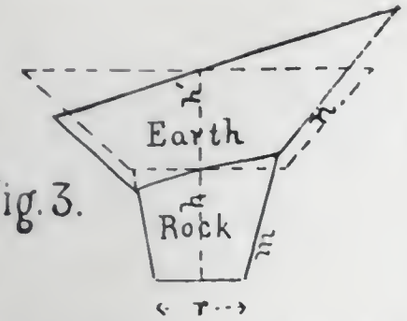
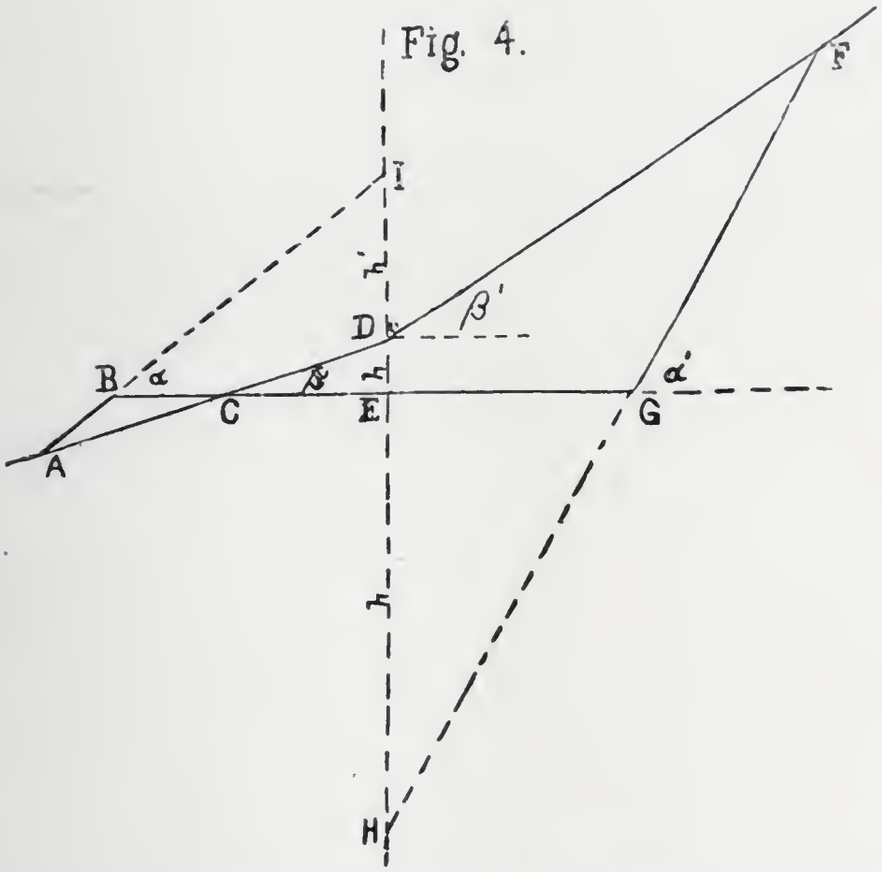


Fig. 3.

For preliminary estimates where the ground slopes are uniform and not steep, it will generally be sufficient to consider the earth section as a trapezoid lying upon a level base, as shown in Fig. 3, in which case we have for the area $(r + 2\,m\,h + n\,h^0)\,h^0$, wherein r = width of roadway in rock, m and n slope ratios of rock and earth, h and h^0 heights of rock and earth.

Side Hill Sections.

Fig. 4.



In the case of side hill sections, as in Fig. 4, it is seen that the excavation area is equal to the triangles $HDF + DCE - GEH$, or when we call

$DE = h$ and $EH = h''$, $\dfrac{(h + h'')^2}{2\,(\text{tang}\,\alpha' - \text{tang}\,\beta')} + \dfrac{h^2}{2\,\text{tang}\,\beta} - \dfrac{h^2}{2\,\text{tang}\,\alpha'}$

In the same way we obtain for the embankment area

$$\frac{(h' - h)^2}{2\,(\text{tang}\,\alpha - \text{tang}\,\beta)} + \frac{h^2}{2\,\text{tang}\,\beta} - \frac{h'^2}{2\,\text{tang}\,\alpha}$$

Practical Use of the Formulæ.

Many formulæ are rejected after mere inspection as being too long and complicated, and often after trial by persons who fail to obtain the best results. Therefore we will proceed to show how to use the foregoing formulæ. Take for instance formula:

$$\frac{(h+h')^2}{2\,(\text{tang}\,\alpha - \text{tang}\,\beta)} + \frac{(h+h')^2}{2\,(\text{tang}\,\alpha + \text{tang}\,\beta')} - \tfrac{1}{4}\,r^2\,\text{tang}\,\alpha,$$

we see directly that h', r and α are constant for each formation.

Place $\dfrac{1}{2\,(\text{tang}\,\alpha - \text{tang}\,\beta)} = p$ and $\dfrac{1}{2(\text{tang}\,\alpha + \text{tang}\,\beta')} = q$,

then the formula reduces to $(h + h')^2\,(p + q) - \frac{1}{4}\,r^2\,\text{tang}\,\alpha$, or leaving off the constant part $(h + h')^2\,(p + q)$. In Table I will be found values of p and q for different formations and slope angles from 0 to 25°. The only labor necessary now is to seek in the table the values p and q, add them together and multiply their sum by the square of $h + h'$, which can be taken from a table of squares. Then from the result subtract the constant area $\frac{1}{4}\,r^2\,\text{tang}\,\alpha$. A table of constants $\frac{1}{4}\,r^2\,\text{tang}\,\alpha$ for different widths of roadway and various formations is also appended.

Performing the multiplication by means of logarithms we have log. $(h + h')$ + log. p, and ^{2} log. $(h + h')$ + log. q for the log. products. In the tables will be found the log. values of p and q.

In order to avoid the multiplication of 100 and division by 27 to get the quantity in cubic yards for the average section, a table is given with the values $p\,\frac{50}{27}$ and $q\,\frac{50}{27}$, so that the cubic yards for the half section may be obtained at once. By adding the results of two consecutive sections we obtain the average quantity in the included station.

For logarithmic work the log. values of $p\,\frac{50}{27}$ and $q\,\frac{50}{27}$ are given.

Following is an example showing how to arrange the work to good advantage: Suppose we wish to work with logs. Fill in columns 1 to 8 of the following table with notes and values from the field-book and our tables. Then seek the values ^{2} log.

$(h + h')$ for section 1, and add it successively to the corresponding value in columns 7 and 8. Place these results in columns 9 and 10, and seek the numbers corresponding in a table of logarithmic numbers; from their sum subtract the constant volume $\frac{50}{4 \times 27} r^2 \text{ tang } a$. Treat section 2 in the same manner and add the result to the quantity obtained for section 1, this sum will be the average quantity for the included station.

Example of Arrangement.

Station.	Elevation.	Grade.	Variation.	$h + h'$	Slopes.	Log. $\frac{50}{27} \times q$	Log. $\frac{50}{27} \times p$	Log. $\left(\frac{50}{27} \times p\right)$ + 2 Log. $(h + h')$	Log. $\left(\frac{50}{27} \times q\right)$ + 2 Log. $(h + h')$	Quantity for the section over 50 feet.	Distance.	Quantity in station.

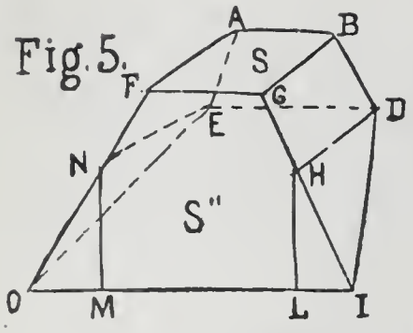
After this example the reader can readily make suitable arrangements for compound sections and side hill work.

Prismoidal Contents.

The former arrangement of the work is intended for preliminary estimates, where it is sufficient to take the average of the end areas to represent the area of the volume in the station.

The true or prismoidal content is given by the following rule: Add together the areas of the two parallel ends of the prismoidal and four times the area of a section half way between, and multiply the sum by one-sixth of the distance between the parallel ends. We have given in our tables the quantities in cubic yards for half sections, in using the prismoidal rule we must divide by three instead of by six, unless we apply it in the following mannner:

Fig. 5.



Let $A\,B\,D\,E\,F\,G\,I\,O$ be our prismoid; pass vertical planes through D and E and parallel to the centre line.

Let c = area $N\,O\,M$ S' = area $F\,G\,I\,O$.

c' = " $H\,I\,L$ $S'' = S' - (c + c')$.

l = dist. bet. sections, $S = A\,B\,D\,E$.

Then we see that the volume of the prismoid is equal to

$$\left\{\left(\frac{S + S''}{2}\right) + \left(\frac{c + c'}{3}\right)\right\} l,$$

but $S'' = S' - (c + c')$; by substituting this volume we get

$$V = \left\{\left(\frac{S + S'}{2}\right) - \left(\frac{c + c'}{6}\right)\right\} l.$$

In taking only the first part of our formula, which is the average of the end area multiplied by the length, we make our content too great, and in case of a great difference between the centre heights of the end sections, the result may differ from the true volume by a considerable amount. The values of c and c' can readily be calculated by formulæ 1.

Approximate Formulæ.

For preliminary estimates it will be sufficiently near to substitute for the values $c + c'$ twice the area of a triangle, whose base is level and whose height is equal to the difference between the centre heights of the two end sections.

Expressing this in a formulæ, we have

$$c' + c' = (h - h^1)^2\, m,$$

wherein m = slope ratio of the formation, h and h^1 are centre heights.

The assumption has thus far been made that the ground slope is regular on each side of the centre line. A method for the treatment of complex slopes is given under the head of Cross-Sectioning.

SECTION II.

Construction and Use of the Diagrams.

In practical work we all recognize the beauty of graphical constructions, especially when they do away with laborious calculations, are easy of comprehension, accurate and capable of being handled with facility by persons of ordinary capacity.

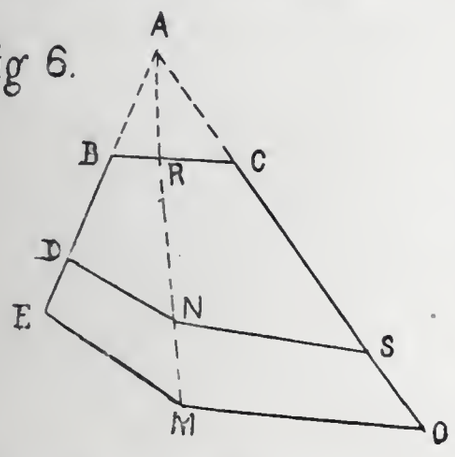
The diagrams we are about to explain possess these qualities, and in addition the especial feature of being easily constructed. Most of the diagrams relating to earthwork calculations are composed of curved or parabolic lines, and each line must be determined by a number of points. Even after the points are calculated for the different curves, the simple mechanical construction of them requires considerable skill and still more patience, and is a task not to be undertaken except by persons who have taste and time for just such work. The few lines of which these diagrams are composed are all straight, and with the aid of the tables given the necessary calculations can be made and a single diagram drawn in less than three hours.

If we take formula 1:

$$\frac{(h+h')^2}{2\,(\text{tang}\,\alpha - \text{tang}\,\beta)} + \frac{(h+h')^2}{2\,(\text{tang}\,\alpha + \text{tang}\,\beta')} - \tfrac{1}{4}\,r^2\,\text{tang}\,\alpha,$$

we see that the two first parts are equations of parabolas. These parabolas can be represented by straight lines by laying off on the axis of abscissas the squares of $(h + h')$ instead of the simple numbers. Or to make the statement of the principle in simpler terms, if $AEMO$ and $ADNS$ are similar figures, then are their areas in the same ratio as the squares of their centre heights, AM and AN.

Fig 6.



This is the principle upon which the diagrams are based. The construction is thus simplified and greater accuracy is attained.

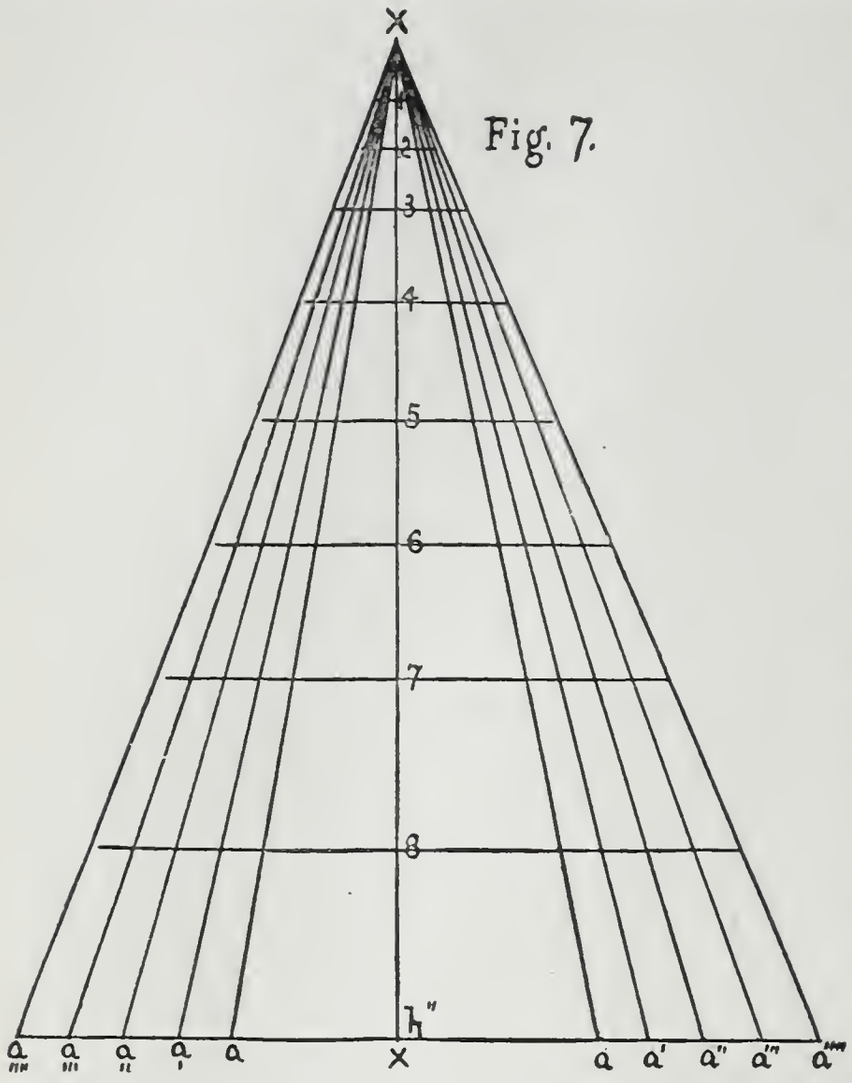


Fig. 7.

To construct the diagrams a line XX is taken as axis, upon which lay off the squares of centre heights from 0 to h''; now for a certain value of $(h + h')$, say h'', calculate the areas A and A' (sec. I, art. 1) for different slope angles of the ground, say from 0° to 25°, and the slope angle of the formation desired. The values thus obtained are laid off to scale on a rectangular ordinate at h''; the values from 0° to + 25° on one side and from 0° to — 25° on the other, and these points a, $a_{,,}$ $a_{,,,}$ and a' a'' a''' connected with the zero point on the axis. Now the length of the ordinate at any point $(h + h')$ of the axis between two lines, corresponding to two slope angles of the ground, represents the sum of the areas A and A'; for the height $(h + h')$. From this area must be subtracted the area of the constant $\frac{1}{4} r^2$ tang α in order to get the area of our section.

In order to avoid this subtraction we read our scale from a new zero point, laid off in a negative direction a distance equal to the value $\frac{1}{4} r^2$ tang α.

For each different formation we have only to construct one diagram, as the formula is independent of the width of roadway.

Accompanying the diagrams are three scales as follows:

1. For reading areas in square feet.
2. " " the quantity in cubic yards for the half area over 100 feet.
3. For use when taking the prismoidal contents, which renders unnecessary the division by 6.

Thus, if on the first scale 1 in. = 300,

" " second " 1 " $= 300 \times \frac{50}{27}$.

" " third " 1 " $= 300 \times \frac{100}{27} \times \frac{1}{6}$.

Since areas are proportional to the squares of centre heights, then are prisms of equal length also proportional to the squares of centre heights, so that instead of taking the areas of our sections and reducing to cubic yards by multiplying by length and dividing by 27, we can use at once a scale of quantities in cubic yards.

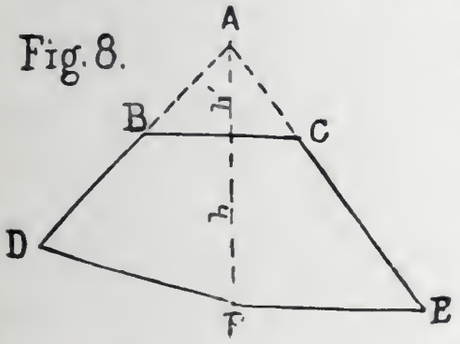
Centre Heights Beyond the Limits of the Diagrams.

Since areas are proportional to the squares of the centre heights, if we divide the centre height by two we must multiply the result by four, or in general, if a centre height is encountered which is beyond the limit of the diagram, divide it by such a number as will render it capable of being treated, and multiply the result by the square of the divisor, observing that the absolute zero of the scale must be used to read from, and the subtraction of the grade area or prism made after this result has been obtained.

Simple Sections.

We will take for example a station in embankment, width of roadway = 32 ft., formation slope 1 to 1, then $h' = 16$ ft., and the volume $ABC \times \frac{50}{27} = 474$. Given centre height = + 25, slope on the left + 5°, on the right — 10°. Add h' to the centre height and enter the diagram with this sum, 41 ft., with the scale for quantities. Place the zero of the scale on the slope line + 5°, at the height 41, and, on the other side of the diagram, at the slope line — 10°, read the quantity, which will be for the area *ADFE;* from this quantity subtract the constant 474. This subtraction can be made on the scale by reading from a new zero point, a dist. to the left equal to the constant to be subtracted, so that the volume read off will be the cubic yards for the area at the section and a length of

Fig. 8.



50 ft. In a similar manner take off the volume at the next section, add the two, and their sum will be the average quantity for the station.

If both sections have the same or nearly the same slopes, right and left, we may apply the prismoidal correction in the following manner: With the scale for correcting quantities enter the diagram at a height equal to the difference between the centre heights at the end sections and the ground slopes, and read off the corresponding quantity, which will be the sum of the two pyramids to be subtracted from the average quantity just found.

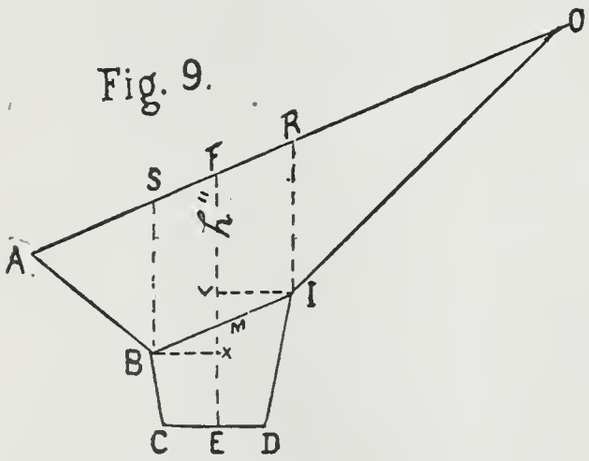
If the ground slopes are widely divergent, apply the prismoidal rule as follows: With the same scale take the volumes corresponding to the end sections, and 4 times the volume for the section midway between them, assuming the slopes for the mid-sections to be the average of the slopes at the end sections. From their sum subtract the grade prism.

These examples will serve for any simple excavation or embankment; observe, however, that every change of roadway and formation slope requires the use of a new set of constants.

Compound Sections.

Let Fig. 9 represent a compound section of rock with earth on top.

Fig. 9.



The rock may be taken out as a simple section by considering the slopes *MB* and *MI* to be the same as *TA* and *TO*. (In this case we add to the centre cut from the field notes the constant height of the grade triangle diminished by the depth of earth.) Then will $SB = RI =$ depth of earth, and the quantities corresponding to *SAB* and *RIO* may be taken at once from the diagram having the same formation slope as is assumed for the earth cutting on top of rock. The area $TSBMIR = h'' \times (IV + BX)$, the distances *IV* and *BX* are given by the formulas

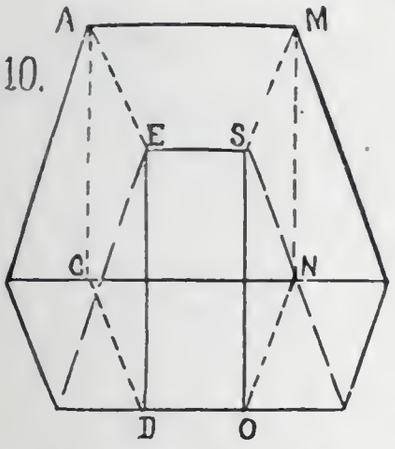
$$IV = \frac{h + h'}{\text{tang } \alpha - \text{tang } \beta}, \quad BX = \frac{h + h'}{\text{tang } \alpha + \text{tang } \beta}.$$

For these dis-

tances we construct a diagram according to this formula. IV and BX vary as the centre heights $(h + h')$, hence our diagram is in simple proportion. Lay off on an axis simple numbers $(h + h')$ to h'''; for h''' calculate the values IV and BX from 0° to 25°, and lay these off on a rectangular ordinate, though h''', as explained before and according to the same scale as the other diagrams, enter this diagram with the same centre height as for rock at that section with the scale of CY, and the ground slopes, TA and TO. Multiply the quantity obtained by h'', the depth of earth, which will give the quantity from 50 ft. for the section $TSBMIR$. The sum of the two quantities thus obtained added to the sum obtained in a similar manner at the next section, gives the CY for the included station.

In a case such as Fig. 10, which represents the earth on top of rock, having end sections of equal depth and level, or the same ground slopes across the section, pass the cutting planes $ACDE$ and $MNOS$, dividing the figure into a prism and two wedges. Now, it will be seen that the true volume is equal to the product of the length multiplied by the mean of the end across, so we see that unless the ground slopes are widely divergent we need make no correction for the earth on top of rock.

Fig. 10.

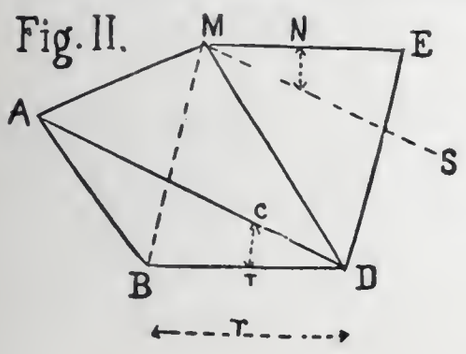


Fading Ends.

The fading ends of excavations and embankments may be estimated by determining the points at which the sections become the base of pyramids, and then the lengths of the pyramids.

Let us examine the figure. $ABDM$ is the terminal pyramid of an excavation, $MBDE$ the plane of the roadway, AD and MS lines on the surface of the ground, at right angles to the centre line, which have slopes θ and a, respectively. Now, at the point where the section becomes the base of a pyramid the centre height

Fig. II.



is CT, which is found by the formula, $CT = \frac{1}{2} r$ tang θ. In a like manner the point at which the pyramid terminates the centre height is NO, and is given by the formula, $NO = \frac{1}{2} r$ tang α.

To find these points graphically, lay off on a horizontal line

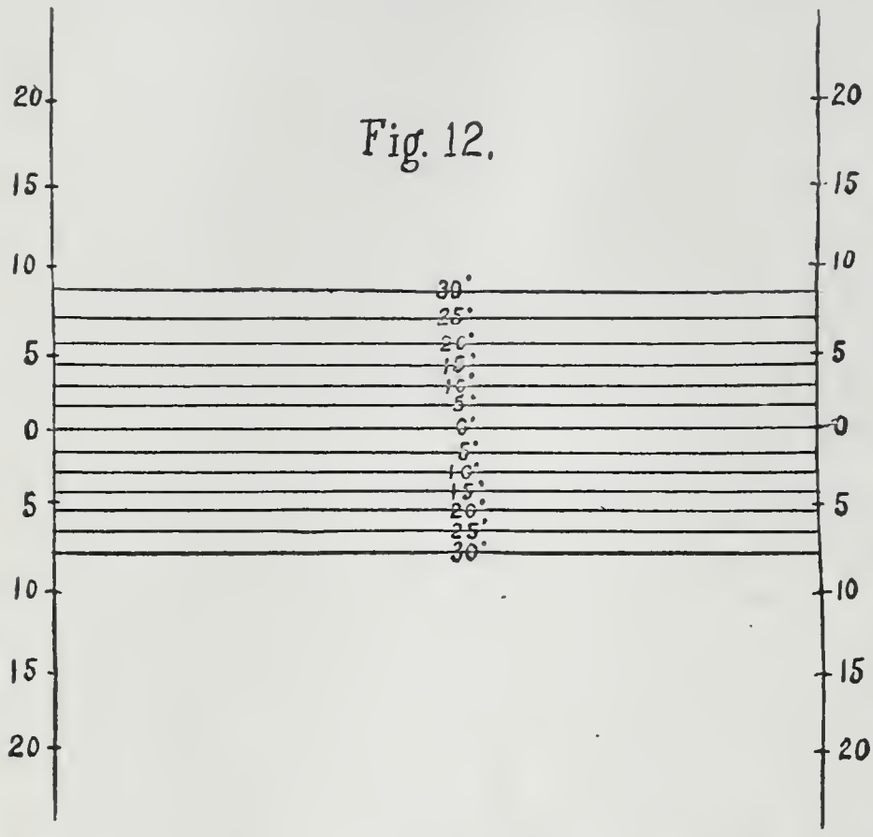


Fig. 12.

100 ft. to any convenient scale to represent the length of a station; at either end erect vertical scales to represent centre heights. Then calculate the values $\frac{1}{2} r$ tang θ from 0° to 25°, and lay off above and below the horizontal line of distances; draw horizontal lines through these points and number them with the number of the degree for which they were calculated. Now, suppose at one end of the station we have a cut of 15 ft. and slope θ, and at the other end a fill of 5 ft. with a slope α. Take a fine thread and hold on one of the upper vertical scales at 15 ft.; then stretch across to the opposite lower scale at 5 ft.; where the thread crosses the upper slope line, θ gives the plus at which the section becomes the base of a pyramid, and the point at which it crosses the lower slope line, α gives the plus at which the pyramid terminates. This result is accurate where θ and α are nearly the same. With another diagram constructed in the same manner, but taking r = width of roadway in embankment, we can get the data for calculating the terminal pyramids in embankments.

But since our data for preliminary estimates is seldom taken with such accuracy as to render such exactness necessary, we may use on the upper side of the distance line the values calculated for width of roadway in excavation, and on the lower side the values calculated for width of roadway in embankment. The

error is very slight, the difference between the centre heights obtained being only $(h - h'') = \frac{1}{2}(r - r')$ tang θ.

To obtain the quantities corresponding, add the constant (h'), then with the scale for correcting quantities enter the proper diagram with the height $(h' + h'')$ and the ground slopes, and read off the volume in cubic yards of the pyramid AVD, which is given on the scale for length of 50 ft.; subtract the pyramid BVD, then double the remainder to reduce to length of 100 ft., and multiply by the actual length expressed as a fractional part of a station. For instance, if the length is 30 ft. multiply by $\frac{3}{10}$.

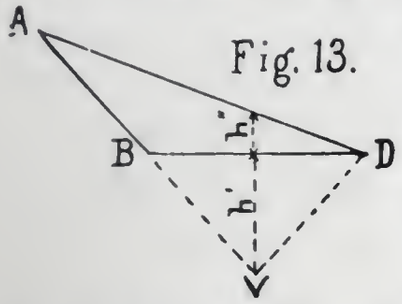


Fig. 13.

Side Hill Work.

We have now but to show how side hill excavations may be treated. Let Fig. 14 represent a section both in excavation and embankment. The portion $FDEG$ may be taken from the diagram for excavation; h'' must first be added, then the quantity FDH is read off, observing in this case only that portion of the diagram is used which lies on the side of the axis corresponding to + slopes for excavation, also that the quantity corresponding to EHG, which is to be subtracted, is but half of that used in through cutting. The excavation corresponding to DCE is taken from the small "auxili-

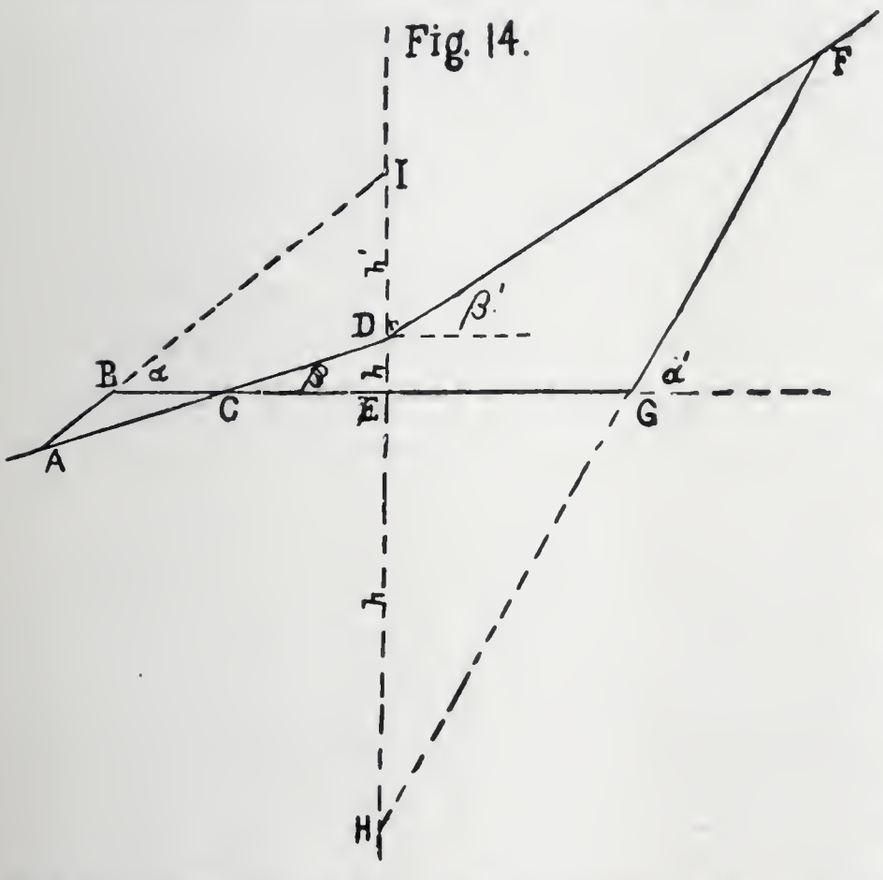


Fig. 14.

ary diagram for side hill work," which is found on the diagrams for excavation and embankment slopes 1 to 1 and $1\frac{1}{2}$ to 1. Enter it at once with the height h and slope β, and scale off the quantity. To obtain IAD we must observe that ID, the centre height at which we are to enter our diagram of embankment, is equal to our usual constant diminished by h. To the quantity obtained for IAD add DCE, and then diminish by IBE. If, instead of having excavation at the centre, we have embankment, take out the embankment in the same manner as we have just taken out excavation, and treat the excavation as we have just treated embankment.

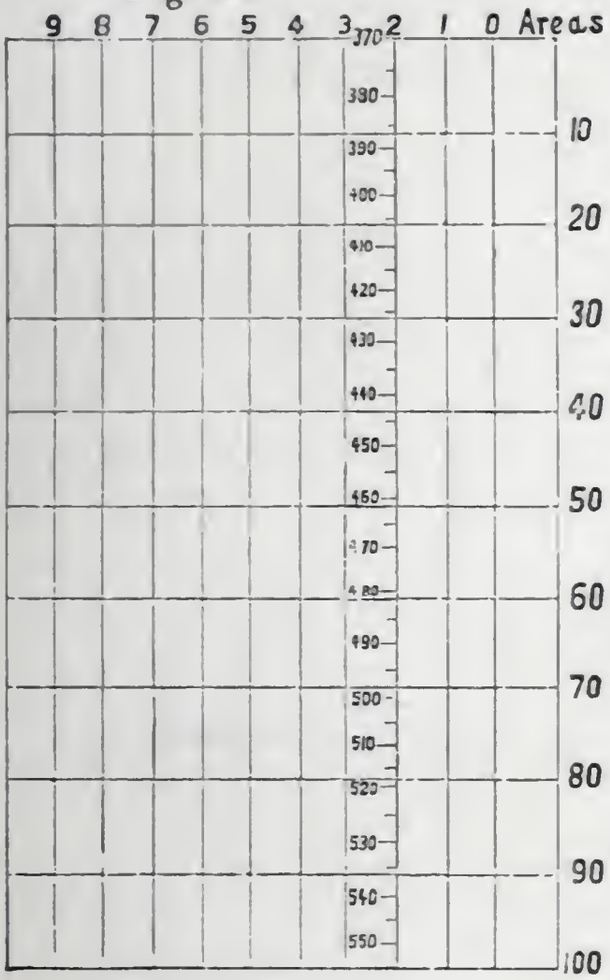
Limit of Side Hill Work.

It is desirable to know at a glance when our section runs into side hill work. The centre height at which the ground just touches the edge of the roadway is given by the formula $h = \frac{1}{2}$ roadway $\times$ tang θ, in which θ is the minus slope in excavation and the plus slope in embankment. The values of h may be calculated for each width of roadway used and for every degree of ground slope to 25°, then add h', our constant for the width of roadway used. At each resulting height make a point on the diagram, the slope line for which that value $h + h'$ was calculated. Through these points draw a curve, which will show the limit of side hill work. Our diagram for terminal pyramids may answer the same purpose, but is not so convenient.

Diagram of Prisms.

The cubic yards in a prism of 100 ft. area and 50 ft. length are nearly 185. Lay off ten vertical lines to any convenient scale, making them 185 divisions long and terminating them on the same horizontal line. Block out and number each fifth division, so it can be easily read. The first scale, which contains the cubic yards for areas less than 100, should be numbered 0, the second, which contains cubic yards for areas between 100 and 200, should be numbered 1, etc., etc. Draw another line of equal

Fig. 15.



length parallel and terminating on the same horizontal line, and divide into 100 parts corresponding to feet of area. Draw horizontal lines through these divisions across the diagram, using for the fifth, tenth and intermediate feet different colored inks. Now, if we want cubic yards corresponding to 256 ft. area and 50 ft. length, look in the column headed 2 on the fifty-sixth line. The nearest yard can be readily estimated if a large enough scale is used in the construction. The greatest error in such a diagram is for 1000 ft. of area, when the discrepancy is 3.7 cubic yards.

SECTION III.

Staking out Work.

The usual method for staking out work and taking cross-sections is with the level. When the side slopes of the ground are steep and the slope of the formation great, this method is long, tedious and liable to involve errors, and is but a method of trial under any circumstances. In the method we describe below, the instrument is set up at the centre, and the whole cross-section taken from this point.

In Sec. 1, Art. 1, we find, for the dist. out of the side stakes, the expressions $\frac{h + h'}{\text{tang } \alpha \pm \text{tang } \beta}$ and $\frac{h + h'}{\text{tang } \alpha \pm \text{tang } \beta'}$. The values

$\frac{1}{\text{tang } \alpha \pm \text{tang } \beta}$ are given in our tables, and may be used for these calculations. But calculations may be avoided by constructing diagrams giving these values of $\frac{h + h'}{\text{tang } \alpha \pm \text{tang } \beta}$. Such a diagram will be in simple proportion, and need not be larger than a page of an ordinary field book. For taking the cross-sections we need the following instruments:—a transit, with vertical arc and level tube on the telescope, for measuring vertical angles; a rod with target, and a tape for measuring horizontal distances. For operating, set the instrument on the centre line at right angles to the tang. at that point where the cross-section is to be taken. Place the target accurately at the height of instrument, estimate the slope angle of the ground, and for that angle and the centre height increased by the constant height h', seek in our diagram the distance of the side stake corresponding. Place the rod at that distance and read the angle to it. If this angle is the same as the angle estimated, the rod is at the right point from the stake. If not, place the rod at the distance corresponding to the angle just read. When the ground is regular, the position of the side stakes may be found with a couple of trials. If care is taken in holding the rod vertical, no serious error can possibly occur in this method. The section is made exactly at right angle to the centre line, and the engineer need not move his instrument from its initial position.

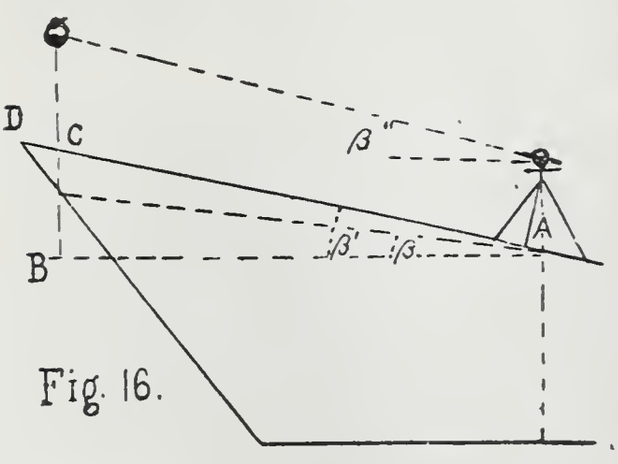


Fig. 16.

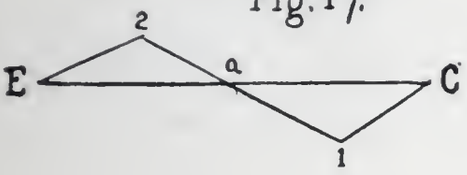
Thus, in Fig. 16, A is the centre of an excavation section, and we wish to find the point D, the position of the side stake. Suppose we had estimated the angle β, which is smaller than the true angle β'. We find then in the diagram the distance AB, and and on the ground the point C instead of D. In placing the rod at C, and reading the angle from that point, we obtain very nearly the correct angle which, sought in the diagram, will give the point D. But even in the event of having to make a half dozen trials, this method will

take less time and involve less labor than will be incurred in leveling up to the point D in the usual manner.

Cross-Sections.

After the positions of the side stakes are found, we make our cross-sections by measuring the angles and distances to all of the intermediate points where the slope of the ground changes.

Fig. 17.



If the slope line from centre to side stake should intersect the ground, as in Fig. 17, the dist. from the centre of this point must be noted.

Facility of Calculation.

Having thus taken the cross-section, the calculation is very much simplified. The greater part of the area is obtained at once from the diagram. We take off the area included by the formation lines and the lines drawn from the centre to the side stakes. Then add or subtract those portions included by the lines drawn from centre to side stakes and the surface lines, as in Fig. 18. The areas AFC must be added and AED must be subtracted.

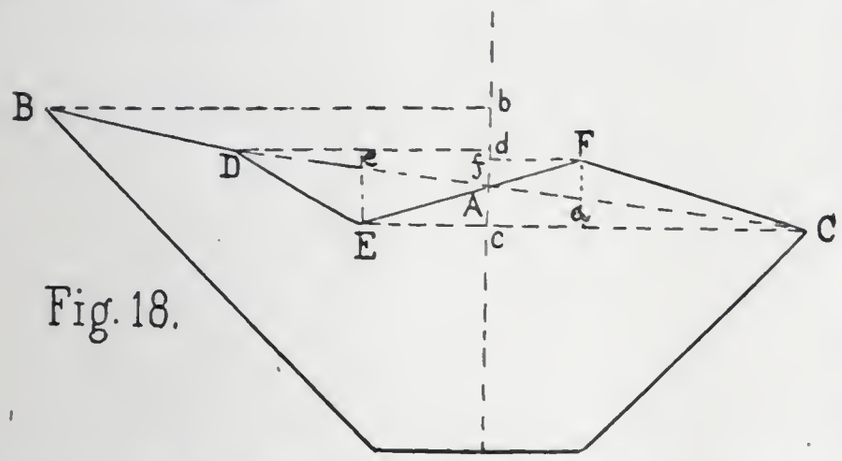


Fig. 18.

These areas are easily calculated without plotting, by observing that the ordinates Ee and Fa are obtained by taking the sum of the tangents of the angles to those points and the side stakes. For instance,

$Fa = Aa(\text{tang } AFf + \text{tang } ACc)$, $Ee = cE(\text{tang } AEc + \text{tang } ABb)$. The general rule is, when the slope angles have opposite signs the tangents are to be added; when they have the same signs they are to be subtracted. The field notes may be kept as follows:

LEFT.				RIGHT.		
$+20°$	$+30°$	$-15°$	station	$-3°$	$+7°$	$+9°$
$80'$	$50'$	$20'$		$10'$	$38'$	85.5

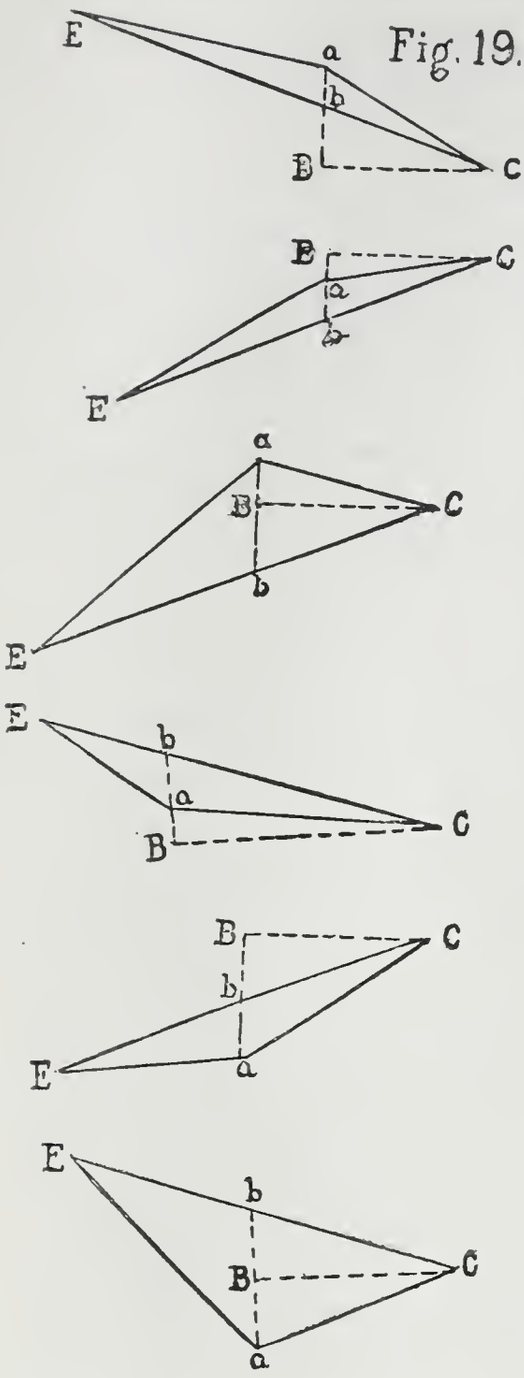


Fig. 19.

Fig. 19 shows most of the cases that will occur in practice. *CCC* are centre stakes, *EEE* side stakes. The larger portion of the section is limited by the line *CE*.

When calculating the areas it will be well for the beginner to keep these sketches before him, in order that he may see whether the portions *CaE* are to be added or subtracted.

The distances *ab* are best obtained by a diagram constructed as follows:

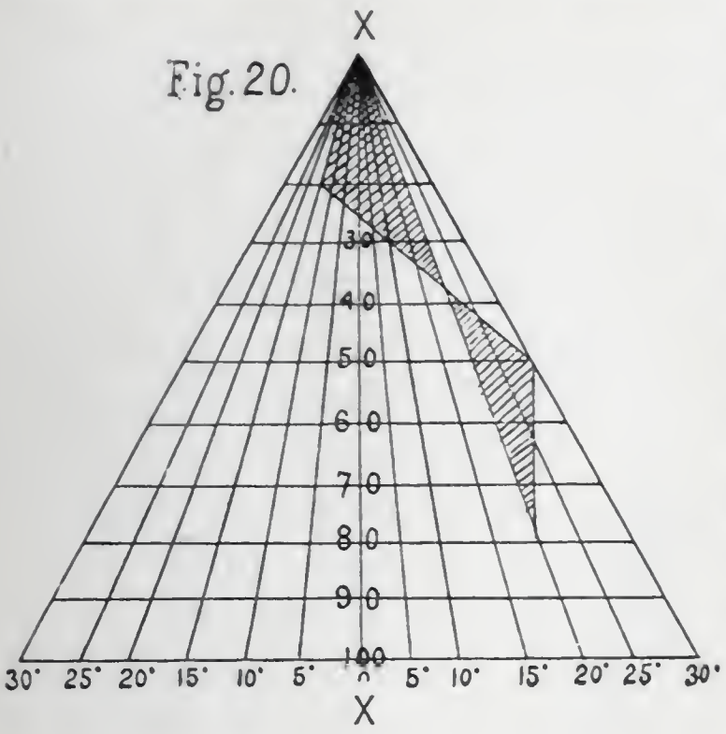
On an axis *XX* (Fig. 20) lay off the distances *CB*, and on rectangular ordinates right and left the tangents for those distances.

Let us take for an example the notes just given:

LEFT.				RIGHT.		
$\frac{+20°}{80}$	$\frac{+30°}{50}$	$\frac{-15°}{20'}$	$\frac{\text{station}}{0}$	$\frac{-3°}{10}$	$\frac{+7°}{38}$	$\frac{+9}{85.5}$

If we plot these on our diagram we begin at zero (see Fig. 20) and follow the —15° line to the intersection with the 20 ft. distance line, thence to the intersection of the + 30° and 50 ft. distance line, thence to the intersection of the 20° and 80 ft. distance line, thence to zero. Now the included area which lies to the left of the + 20° line is to be subtracted from the area

Fig. 20.



obtained for the side stakes, and the included area lying to the right of the + 20° line is to be added. The notes of the right side of the section are to be traced in the same manner. If we use the planimeter to obtain these areas we need not plot the section, but simply run over it with the planimeter point.

SECTION IV.

Graphical Determination of the Distance of Haul.

This method of calculating the dist. of haul is very generally used in Germany, and gives a quick and accurate result, and is recommended especially for its simplicity and elegance of representation. In Germany this method is known under the name of "*Massennivellement*," which, translated literally, means "Leveling of Masses."

The principle is as follows. We lay off on vertical ordinates in each station the quantity lying between this station and a certain starting point in the line chosen arbitrarily, *i.e.*, we add successively all the quantities and lay off on ordinates these summations at the points where they are made, observing that excavation and embankment are to be taken with opposite signs. Further, excavated material, which increases with loosening, is to be augmented by this increase before being summated. A line through the limits of the ordinates thus obtained gives us a curve, which we call a "Distribution Profile."

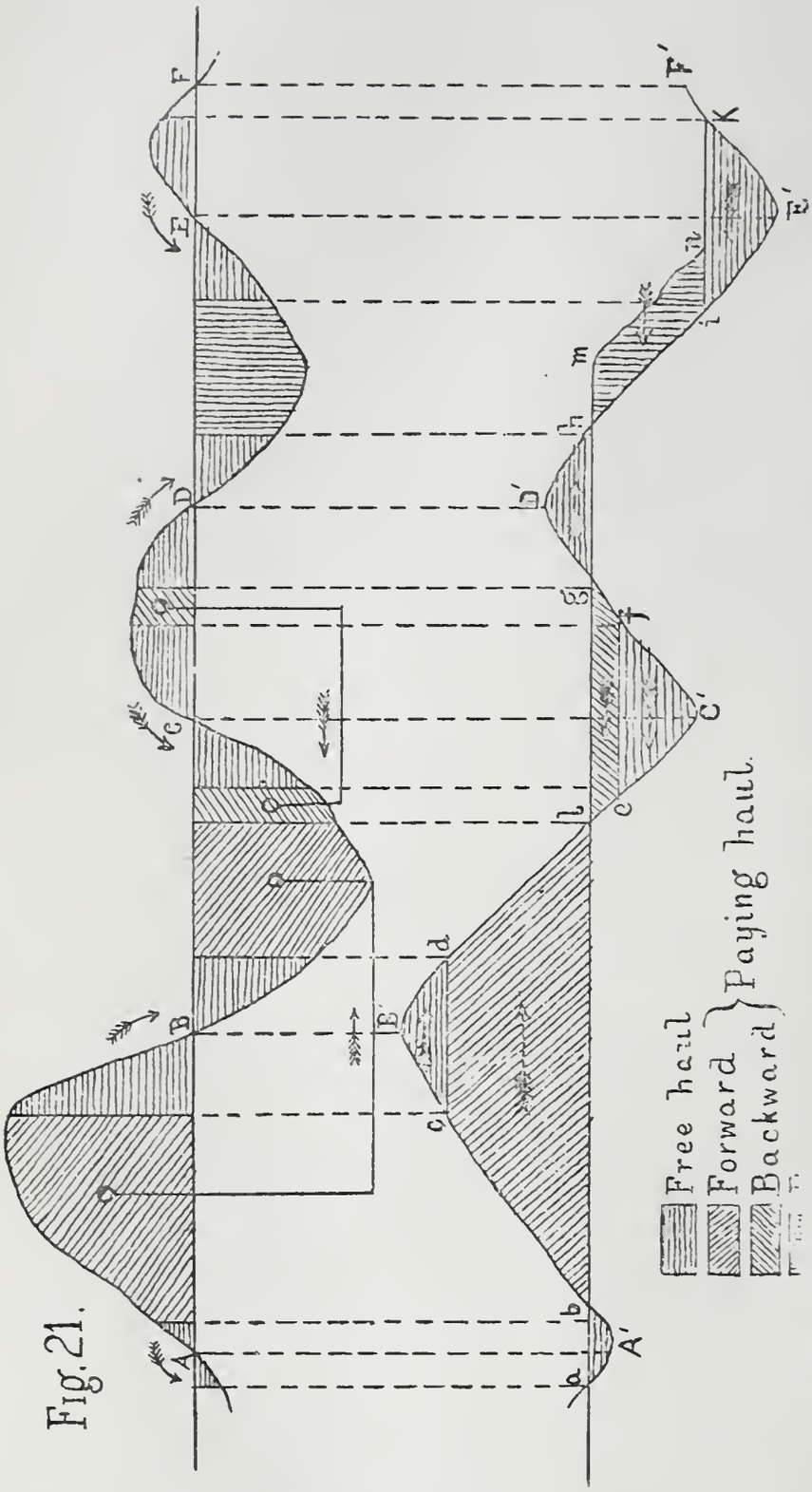


Fig. 21.

The upper part of Fig. 21 represents an ordinary profile; the lower part represents the corresponding "Distribution Profile." Comparing these, we observe—

1st. The grade points in the ordinary profile correspond with maximum and minimum points in the "Distribution Profile."

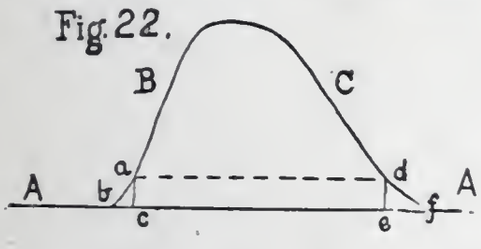
2d. Excavation forms an ascending line and embankment a descending line.

3d. The difference between the lengths of two vertical ordinates represents the quantity lying between the points at which the ordinates are erected.

4th. Between two points where the "Distribution Profile" is intersected by any horizontal line the excavation is equal to the embankment.

We can thus at a glance determine the points between which there will be neither borrow nor overhaul. But for each case there is but a single line which fulfils the condition of most economical distribution. It is not, however, our intention to discuss this subject fully, but only to apply it to the common practice of this country. In ordinary practice the limit of free

haul is usually assumed as 1000 ft.; everything beyond this point is paid for as overhaul, the question of most economical distribution not usually being fully considered. We have now but to seek either side of the grade points, the stations lying at the specified dist. apart between which excavation equals embankment. Observing Rule 4, we can easily find these stations by tracing the lines *ab*, *cd*, *ef*, *ik* equal to the distance of free haul. Having thus determined the quantities of free haul, we have next to calculate the overhaul.



Let Fig. 22 represent a part of a distribution profile; AA, a horizontal line; B, excavation, equal to embankment, C. Then the product of the excavation B multiplied by the distance its centre of gravity is moved in making it into the embankment C, is equal to the area included by the curve BC and the line AA. Let us consider an infinitesimal portion of our profile represented by $aC = dE$. The total haul of this portion is represented by the product $ac \times ad$, which is also the expression for the area *aced*. Now, if we summate these products, we obtain, for the product of the whole mass of excavation multiplied by the distance it is moved, the area $ABCA$. Hence, having our distribution profile, and wishing to know the haul of any portion, as B, measure the area $ABCA$ with a planimeter and divide this area by the ordinate representing the excavation B. The result will be the distance between the centres of gravity of B and C.

TABLE I.

SLOPES.	$\frac{10000}{2\ (\mathrm{tg}\ \alpha + \mathrm{tg}\ \beta)}$					$\frac{10000}{2\ (\mathrm{tg}\ \alpha - \mathrm{tg}\ \beta)}$					SLOPES.
	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	
0	7500	5000	3750	2500	1250	7500	5000	3750	2500	1250	0
1	7310	4914	3702	2478	1245	7704	5089	3801	2522	1255	1
2	7127	4835	3655	2457	1239	7914	5181	3852	2544	1261	2
3	6953	4751	3609	2436	1234	8140	5276	3903	2566	1266	3
4	6789	4673	3564	2410	1229	8379	5376	3959	2590	1272	4
5	6629	4598	3519	2395	1223	8633	5479	4014	2614	1278	5
6	6479	4524	3476	2375	1218	8904	5587	4072	2639	1284	6
7	6333	4453	3434	2355	1213	9193	5700	4132	2664	1290	7
8	6194	4384	3393	2336	1208	9503	5817	4193	2689	1296	8
9	6060	4316	3352	2316	1202	9838	5941	4257	2715	1302	9
10	5931	4250	3312	2297	1197	10196	6070	4323	2742	1308	10
11	5807	4186	3273	2278	1192	10587	6207	4392	2769	1314	11
12	5686	4123	3234	2260	1187	11012	6350	4462	2797	1320	12
13	5570	4062	3197	2241	1182	11474	6501	4537	2826	1327	13
14	5458	4002	3159	2223	1177	11980	6660	4625	2856	1333	14
15	5350	3943	3122	2205	1172	12549	6830	4695	2886	1340	15
16	5244	3886	3086	2187	1166	13160	7010	4778	2918	1347	16
17	5142	3830	3051	2169	1161	13852	7202	4866	2951	1354	17
18	5042	3774	3016	2150	1156	14631	7406	4960	2985	1361	18
19	4945	3719	2980	2133	1151	15511	7625	5058	3020	1368	19
20	4851	3666	2945	2115	1146	16521	7861	5160	3056	1375	20
21	4759	3613	2912	2097	1140	17683	8115	5269	3094	1383	21
22	4670	3561	2879	2080	1135	19037	8389	5382	3133	1390	22
23	4582	3510	2845	2062	1130	20648	8688	5504	3174	1398	23
24	4497	3460	2811	2045	1125	22576	9012	5631	3215	1407	24
25	4413	3410	2779	2027	1120	24956	9369	5770	3261	1415	25
26	4331	3361	2746	2010	1114	27940	9760	5914	3306	1423	26
27	4251	3312	2714	1993	1109	31817	10194	6072	3355	1433	27
28	4172	3265	2681	1975	1103	37051	10677	6238	3405	1442	28
29	4095	3216	2649	1957	1098	44504	11218	6423	3459	1451	29
30	4019	3169	2616	1939	1092	56023	11832	6618	3515	1461	30

TABLE II.

$$\frac{50}{27} \times \frac{10000}{2\,(\mathrm{tg}\ \alpha + \mathrm{tg}\ \beta)} \qquad \frac{50}{27} \times \frac{10000}{2\,(\mathrm{tg}\ \alpha - \mathrm{tg}\ \beta)}$$

SLOPES.	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	SLOPES.
0	13893	9260	6945	4629	2315	13893	9260	6945	4629	2315	0
1	13536	9100	6857	4589	2305	14266	9423	7039	4671	2325	1
2	13198	8945	6769	4550	2295	14656	9594	7134	4701	2335	2
3	12876	8796	6682	4511	2285	15073	9770	7228	4753	2345	3
4	12572	8654	6600	4463	2275	15517	9954	7332	4797	2356	4
5	12280	8513	6518	4435	2265	15988	10147	7434	4842	2367	5
6	11995	8379	6437	4399	2255	16452	10347	7540	4887	2377	6
7	11727	8245	6359	4361	2245	17026	10556	7653	4933	2388	7
8	11474	8119	6284	4325	2236	17600	10773	7764	4980	2399	8
9	11223	7993	6207	4290	2226	18218	11003	7883	5028	2411	9
10	10982	7871	6134	4254	2217	18885	11241	8006	5078	2422	10
11	10755	7752	6062	4219	2208	19607	11495	8132	5129	2433	11
12	10527	7637	5990	4185	2198	20394	11760	8264	5180	2445	12
13	10316	7522	5920	4151	2188	21247	12040	8402	5233	2457	13
14	10109	7410	5851	4116	2179	22188	12334	8545	5289	2469	14
15	9908	7303	5784	4082	2169	23223	12648	8693	5346	2481	15
16	9687	7198	5715	4050	2160	24367	12981	8847	5404	2494	16
17	9521	7093	5650	4016	2150	25651	13336	9012	5464	2506	17
18	9339	6987	5585	3982	2141	27096	13715	9186	5528	2520	18
19	9158	6887	5520	3949	2131	28721	14123	9367	5592	2533	19
20	8984	6787	5486	3916	2122	30592	14558	9554	5660	2546	20
21	8815	6690	5393	3883	2112	32750	15028	9757	5729	2560	21
22	8650	6595	5331	3852	2102	35254	15535	9966	5801	2575	22
23	8486	6500	5269	3819	2093	38239	16088	10191	5876	2589	23
24	8327	6408	5206	3787	2083	41812	16688	10426	5954	2604	24
25	8171	6314	5146	3754	2073	46217	17350	10686	6038	2621	25
26	8020	6225	5085	3722	2063	51737	18072	10950	6122	2636	26
27	7874	6133	5026	3690	2053	58790	18876	11243	6212	2653	27
28	7725	6045	4965	3658	2043	68612	19770	11553	6305	2669	28
29	7582	5957	4906	3625	2033	82585	20773	11893	6405	2687	29
30	7442	5870	4846	3593	2023	103755	21908	12254	6509	2705	30

TABLE III.

SLOPES.	$\text{Log}\frac{1000}{2(\text{tg}\ \alpha + \text{tg}\ \beta)}$ $1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\text{Log}\frac{1000}{2(\text{tg}\ \alpha - \text{tg}\ \beta)}$ $1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	SLOPES.
0	2.8752	2.6990	2.5741	2.3979	2.0969	2.8752	2.6990	2.5741	2.3979	2 0969	0
1	2.8639	2.6914	2.5685	2.3941	2.0950	2 8867	2.7066	2.5799	2.4018	2.0988	1
2	2.8529	2.6840	2.5629	2.3904	2.0931	2.8984	2.7144	2.5857	2.4056	2.1007	2
3	2.8422	2.6767	2.5574	2.3867	2.0912	2.9106	2.7223	2.5914	2.4094	2.1026	3
4	2.8318	2.6696	2.5519	2.3820	2.0894	2.9232	2.7304	2 5976	2.4134	2.1046	4
5	2.8216	2.6625	2.5465	2.3793	2.0875	2.9362	2.7387	2.6036	2.4174	2.1065	5
6	2 8114	2.6556	2.5411	2.3757	2.0857	2.9496	2.7472	2.6098	2.4214	2.1085	6
7	2.8016	2.6486	2.5358	2.3720	2.0838	2.9635	2.7559	2.6162	2.4255	2.1105	7
8	2.7921	2.6419	2.5306	2.3685	2.0819	2.9779	2.7647	2.6225	2.4296	2.1124	8
9	2.7825	2.6351	2.5253	2.3648	2.0800	2.9929	2.7739	2.6291	2.4338	2.1145	9
10	2.7731	2.6284	2.5201	2.3612	2.0782	3.0085	2.7832	2.6358	2.4381	2.1165	10
11	2.7640	2.6218	2.5150	2.3576	2.0763	3.0248	2.7929	2.6426	2.4424	2.1186	11
12	2.7547	2.6153	2.5098	2.3541	2.0744	3.0419	2.8028	2.6496	2.4467	2.1206	12
13	2.7459	2.6087	2.5047	2.3505	2.0725	3.0597	2.8130	2.6568	2.4512	2.1227	13
14	2.7371	2.6022	2.4996	2.3469	2.0706	3.0785	2.8235	2.6641	2.4558	2.1249	14
15	2.7284	2.5959	2.4946	2.3433	2.0687	3.0983	2.8344	2.6716	2.4604	2.1270	15
16	2.7196	2.5896	2.4895	2.3398	2.0668	3.1192	2.8457	2.6792	2.4651	2.1292	16
17	2.7111	2.5832	2.4844	2.3362	2.0649	3.1415	2.8574	2.6872	2.4699	2.1314	17
18	2.7027	2.5768	2.4794	2.3325	2.0630	3.1653	2.8696	2.6955	2.4749	2.1337	18
19	2.6942	2.5704	2.4743	2.3289	2.0610	3.1906	2.8823	2.7040	2.4800	2.1360	19
20	2.6859	2.5642	2.4693	2.3253	2.0591	3.2180	2.8955	2.7126	2.4852	2.1383	20
21	2.6776	2.5578	2.4642	2.3217	2.0571	3.2476	2.9093	2.7217	2.4905	2.1407	21
22	2.6694	2.5516	2.4592	2.3180	2.0551	3.2796	2.9237	2.7309	2.4959	2.1432	22
23	2.6611	2.5453	2.4541	2.3143	2.0531	3.3149	2.9389	2.7406	2.5016	2.1456	23
24	2.6529	2.5391	2.4489	2.3107	2.0511	3.3537	2.9548	2.7506	2.5072	2.1481	24
25	2.6447	2 5328	2.4438	2.3069	2.0490	3.3972	2.9717	2.7612	2.5133	2.1508	25
26	2.6366	2.5265	2.4387	2.3032	2.0470	3.4462	2.9894	2.7719	2.5193	2.1533	26
27	2.6286	2.5201	2.4336	2.2994	2.0448	3.5027	3.0083	2.7833	2.5256	2.1561	27
28	2.6203	2.5139	2.4283	2.2956	2.0427	3.5688	3.0284	2.7951	2.5321	2.1588	28
29	2.6123	2.5074	2.4231	2.2917	2.0405	3.6484	3.0499	2.8077	2.5389	2.1617	29
30	2.6041	2.5010	2.4178	2.2878	2.0383	3.7484	3.0730	2.8207	2.5459	2.1646	30

TABLE IV.

$$\text{Log}\,\frac{50}{27} \times \frac{1000}{2\,(\text{tg}\,\alpha + \text{tg}\,\beta)} \qquad \text{Log}\,\frac{50}{27} \times \frac{1000}{2\,(\text{tg}\,\alpha - \text{tg}\,\beta)}$$

SLOPES.	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	SLOPES.
0	3.1428	2.9666	2.8417	2.6655	2.3645	3.1428	2.9666	2.8417	2.6655	2.3645	0
1	3.1315	2.9590	2.8361	2.6617	2.3626	3.1543	2.9742	2.8475	2.6694	2.3664	1
2	3.1205	2.9516	2.8305	2.6580	2.3607	3.1660	2.9820	2.8533	2.6722	2.3683	2
3	3.1098	2.9443	2.8249	2.6543	2.3588	3.1782	2.9899	2.8590	2.6770	2.3702	3
4	3.0994	2.9372	2.8195	2.6496	2.3570	3.1908	2.9980	2.8652	2.6810	2.3722	4
5	3.0892	2.9301	2.8141	2.6469	2.3551	3.2038	3.0063	2.8712	2.6850	2.3741	5
6	3.0790	2.9232	2.8087	2.6433	2.3532	3.2162	3.0148	2.8774	2.6890	2.3761	6
7	3.0692	2.9162	2.8034	2.6396	2.3513	3.2311	3.0235	2.8838	2.6931	2.3781	7
8	3.0597	2.9095	2.7982	2.6360	2.3495	3.2455	3.0323	2.8901	2.6972	2.3800	8
9	3.0501	2.9027	2.7929	2.6324	2.3476	3.2605	3.0415	2.8967	2.7014	2.3821	9
10	3.0407	2.8960	2.7877	2.6288	2.3457	3.2761	3.0508	2.9034	2.7057	2.3841	10
11	3.0316	2.8894	2.7826	2.6255	2.3439	3.2924	3.0605	2.9102	2.7100	2.3862	11
12	3.0223	2.8829	2.7774	2.6217	2.3420	3.3095	3.0704	2.9172	2.7143	2.3882	12
13	3.0135	2.8763	2.7723	2.6181	2.3401	3.3273	3.0806	2.9244	2.7188	2.3903	13
14	3.0047	2.8698	2.7672	2.6145	2.3382	3.3461	3.0911	2.9317	2.7234	2.3925	14
15	2.9960	2.8635	2.7622	2.6109	2.3353	3.3659	3.1020	2.9392	2.7280	2.3946	15
16	2.9862	2.8572	2.7570	2.6074	2.3345	3.3868	3.1133	2.9468	2.7327	2.3968	16
17	2.9787	2.8508	2.7520	2.6038	2.3325	3.4091	3.1250	2.9548	2.7375	2.3990	17
18	2.9703	2.8443	2.7470	2.6001	2.3306	3.4329	3.1372	2.9631	2.7426	2.4013	18
19	2.9618	2.8380	2.7419	2.5965	2.3286	3.4582	3.1499	2.9716	2.7476	2.4036	19
20	2.9535	2.8317	2.7369	2.5929	2.3267	3.4856	3.1631	2.9802	2.7528	2.4059	20
21	2.9452	2.8254	2.7318	2.5892	2.3247	3.5152	3.1769	2.9893	2.7581	2.4083	21
22	2.9370	2.8192	2.7268	2.5856	2.3227	3.5472	3.1913	2.9985	2.7635	2.4108	22
23	2.9287	2.8129	2.7217	2.5819	2.3207	3.5825	3.2065	3.0082	2.7691	2.4132	23
24	2.9205	2.8067	2.7165	2.5783	2.3187	3.6213	3.2224	3.0181	2.7748	2.4157	24
25	2.9123	2.8003	2.7114	2.5745	2.3166	3.6648	3.2393	3.0288	2.7809	2.4184	25
26	2.9042	2.7941	2.7063	2.5708	2.3145	3.7138	3.2570	3.0394	2.7869	2.4210	26
27	2.8962	2.7877	2.7012	2.5670	2.3124	3.7693	3.2759	3.0509	2.7932	2.4237	27
28	2.8879	2.7814	2.6959	2.5632	2.3103	3.8364	3.2960	3.0627	2.7997	2.4264	28
29	2.8798	2.7750	2.6907	2.5593	2.3081	3.9160	3.3175	3.0753	2.8065	2.4293	29
30	2.8717	2.7686	2.6854	2.5554	2.3059	4.0160	3.3406	3.0883	2.8135	2.4322	30

TABLE V.

LIMITS OF HEIGHTS FOR DIFFERENT WIDTHS OF ROADWAY.

SLOPES.	10	12	14	16	18	20	22	24	26	28	30	32
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6
3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.8
4	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.1
5	0.4	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4
6	0.5	0.6	0 7	0.8	1.0	1.1	1.1	1 2	1.3	1.5	1.6	1.7
7	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0
8	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2 3
9	0.8	0.9	1.1	1.3	1.5	1.6	1.7	1.9	2 1	2.3	2.4	2.5
10	0.9	1.1	1.2	1.4	1.7	1.8	2.0	2 1	2.3	2.6	2.6	2.8
11	1.0	1.2	1.3	1.6	1.8	1.9	2.2	2.3	2.6	2.8	2.9	3.1
12	1.1	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.0	3.2	3.4
13	1.2	1.4	1.6	1.8	2.1	2.3	2.6	2.8	3.0	3.3	3.5	3.7
14	1.2	1.5	1.7	2.0	2.3	2.5	2.7	2.9	3.2	3.5	3.7	4.0
15	1.3	1.6	1.9	2.1	2.5	2.7	2.9	3.2	3.4	3.8	4.0	4.3
16	1.4	1.7	2.0	2.3	2.7	2.9	3.1	3.4	3.7	4.1	4.3	4.6
17	1.5	1.8	2.1	2.4	2.9	3.1	3.3	3.6	3.9	4.4	4.6	4.8
18	1.6	2.0	2.3	2.6	3.0	3.3	3.6	3.9	4.2	4.6	4.9	5.1
19	1.7	2.1	2.4	2.8	3.2	3.4	3.8	4.1	4.5	4.9	5.2	5.5
20	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.3	4.7	5.1	5.5	5.8
21	1.9	2.3	2.7	3.1	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.1
22	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.1	6.5
23	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1	5.5	5.9	6.4	6.8
24	2.2	2.7	3.1	3.6	4.0	4.5	4.9	5.3	5.8	6.2	6.7	7.1
25	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.0	6.5	7.0	7.5
26	2.4	2.9	3.4	3.9	4.4	4.9	5.3	5.8	6.3	6.8	7.3	7.8
27	2.5	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.2
28	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	7.0	7.5	8.0	8.5
29	2.8	3.3	3.9	4.4	5.0	5.5	6.1	6.7	7.2	7.8	8.3	8.9
30	2.9	3.5	4.0	4.6	5.2	5.8	6.4	6.9	7.5	8.1	8.7	9.2

TABLE VI.

VALUES OF CONSTANTS.

ROADWAYS.	$1\frac{1}{2}$		$\frac{1}{1}$		$\frac{3}{4}$		$\frac{1}{2}$		$\frac{1}{4}$	
	h'	$\frac{1}{2} r^2$ tg a.	h'	$\frac{1}{2} r^2$ tg a.	h'	$\frac{1}{2} r^2$ tg a.	h'	$\frac{1}{2} r^2$ tg a.	h'	$\frac{1}{2} r^2$ tg a.
10	3.3	16	5	25	6.7	32	10	50	20	100
12	4.0	24	6	36	8.0	48	12	72	24	144
14	4.7	33	7	49	9.3	66	14	98	28	196
16	5.3	42	8	64	10.7	84	16	128	32	256
18	6.0	54	9	81	12.0	108	18	162	36	324
20	6.7	67	10	100	13.3	134	20	200	40	400
22	7.3	80	11	121	14.7	160	22	242	44	484
24	8.0	96	12	144	16.0	192	24	288	48	576
26	8.7	113	13	169	17.3	226	26	338	52	676
28	9.3	130	14	196	18.7	260	28	392	56	784
30	10.0	150	15	225	20.0	300	30	450	60	900
32	10.7	171	16	256	21.3	342	32	512	64	1024

PROC. ENG. CLUB OF PHILA., 1884
VOL. IV. NO. 2.
PLATE VI

THIANGE'S DIAGRAMS

FOR OBTAINING WITHOUT CALCULATIONS

END AREAS AND TRUE PRISMOIDAL CONTENTS

OF SIMPLE AND COMPOUND

RAILROAD EARTHWORK FORMATIONS

DIRECT FROM

CENTRE HEIGHTS AND SIDE SLOPES

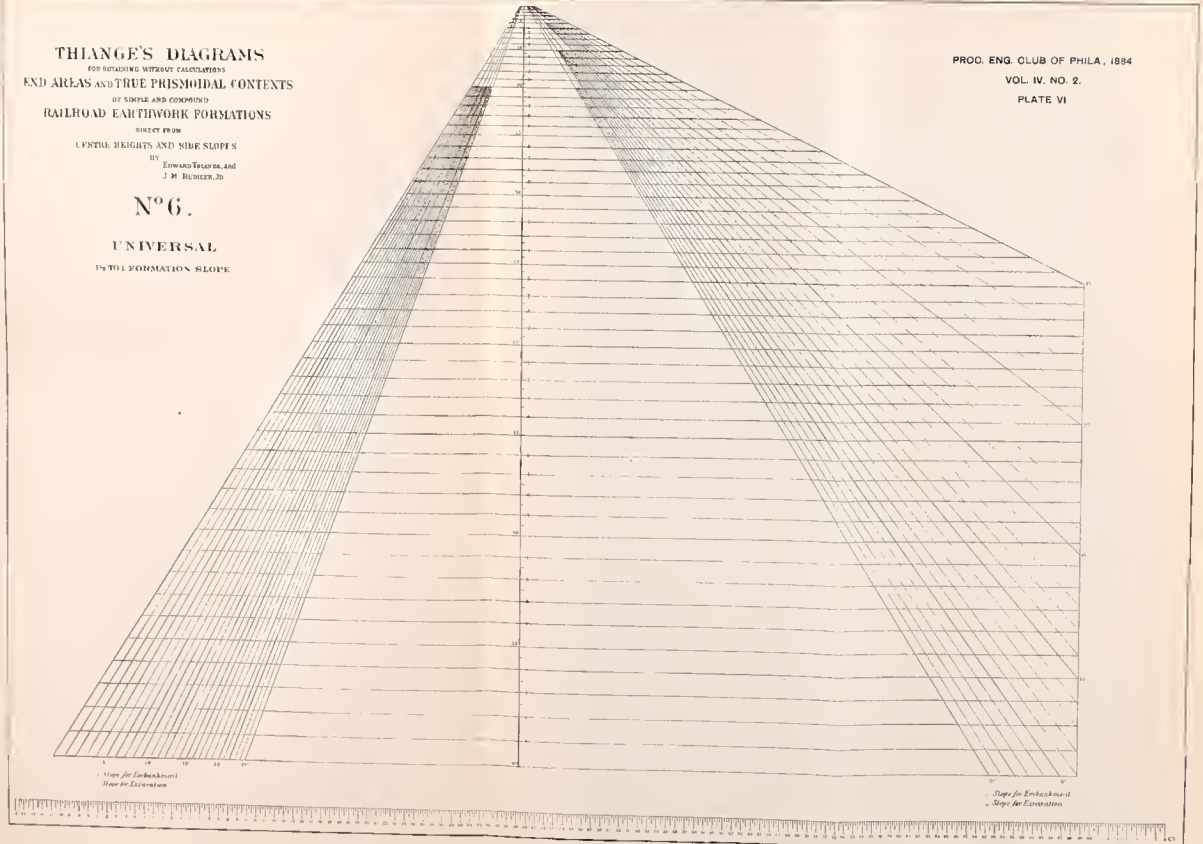
BY

EDWARD THIANGE, and
J. H. RUDIGER, Jr.

N°6.

UNIVERSAL

1½ TO 1 FORMATION SLOPE



VII.

OBSERVATIONS ON THE CRUSHING STRENGTH OF ICE

By Col. William Ludlow, President of the Club.

Read March 1st, 1884.

In 1880 and 1881, while in charge of the Government operations for the improvement of the Delaware River, I had under consideration the construction of an Ice Harbor at Liston's Point, a well-known locality half-way between Philadelphia and the sea, at what might be called the head of Delaware Bay, where the river broadens into the estuary.

The width between shores in this vicinity is about two miles, the channel lying midway; and a careful consideration of the general and local conditions led to the conclusion, that in order to meet most fully the requirements and convenience of the Delaware commerce, the proposed ice harbor should be detached from the shore, while so located as to be readily accessible from the channel. Furthermore, it seemed probable that the best results, economically and otherwise, might be obtained by departing from the usual plan of constructing the ice harbor of individual massive stone piers resting upon wooden piles or crib work, and substituting therefor a continuous structure standing upon iron piles, which would offer less resistance to the flow of water and still furnish proper security against the movement of floating ice.

The harbor was therefore designed as a quadrangular area enclosed between two lines of pier, each pier consisting of two lines united at angles looking respectively up and down stream, with open entrances from the East and West.

The piers were to be built of trestles, each consisting of four piles, two upright and two inclined, screwed into the bottom and suitably connected at the top and at the several intersections.

In considering what should be the dimensions of the several parts in order to secure the stability of the structure and the safety of vessels taking shelter, it was necessary to investigate the forces which must be met and overcome. The structure being open and the deck elevated above the water, there was no question as to the effect upon it of the movements of waves or currents. Collisions need not be considered, since they would not be likely to occur under proper management, and every possibility of this

kind could not be adequately anticipated nor provided against in any event. The most formidable destructive agent would be floating masses of ice, and it remained, therefore, to make such provision against this as a careful investigation should seem to warrant; and first to determine the strains to which the structure might be subjected from this cause.

To attempt to compute the total thrust of an ice-field was manifestly useless, since practically no limits could be assigned to its area and weight, and the momentum of a floe would be theoretically irresistible. It becomes evident, then, that considering the impact of a moving mass of ice, the greatest effort required of an opposed force is that which would be sufficient to cleave its way through the moving floe by crushing the ice in contact with it—in other words, that the ultimate pressure would be limited by the crushing strength of ice, and that if a given member were competent to withstand this, the structure would be stable.

In looking about for information on this subject, I was surprised to find that while the general subject of ice pressures was frequently referred to, and striking examples were given of the destructive action of ice under various circumstances, a diligent search of the Engineering Records that were available at Washington, New York, Philadelphia, and elsewhere, in official reports and the proceedings of engineering societies and technical journals, domestic and foreign, showed nearly an absolute dearth of exact information on this subject.

In the Report of a Board of Engineers, in 1845, on file in the office of the Chief of Engineers at Washington, an attempt was made to ascertain what would be the effect of an acre of ice from 12 to 15 inches thick, moving with a velocity of 3 feet per second and impinging against a breakwater. The result arrived at was that under such circumstances a pressure of $27\frac{11}{100}$ tons would be exerted against each foot front of the structure, equivalent apparently to a pressure of 425 lbs. to the square inch; but I was in the end unable to determine from the data given what pressure per square inch of surface was really intended.

A discussion in the Annual Report of the Illinois and St. Louis Bridge Company for 1868, sought to determine what would be the pressure of the ice against the piers of the bridge.

The discussion began with the assumption (for which no

authority was presented) that the crushing strength of ice is 600 lbs. per square inch, and by a series of mathematical reasoning and transformations, it was finally shown that the pressure of an impinging floe 500,000 square feet in area and $1\frac{2}{10}$ feet in thickness against a pier, would be about $43\frac{2}{10}$ tons per square foot. Reducing this to pressure per square inch at 2,000 lbs. to the ton, it appeared that the pressure deduced was precisely that with which the investigation began, namely, 600 lbs.

This closing of the circuit tended to show that the pressure would be independent of the actual dimensions of the floe, but it manifestly remained to determine by experiment the validity of the 600 lbs. assumption. For this purpose advantage was first taken of a small Testing Machine in use at the Frankford Arsenal. It had many defects, however, and satisfactory results were not secured by its use. A much better machine was at Fort Tompkins, on Staten Island, on which the pressures were indicated by gauges instead of by weights as in the Frankford machine, and which had been used for the purpose of crushing blocks of stone and cement. It was therefore of ample power.

In making the tests, the ice blocks were procured from several sources—pond ice, Delaware ice, and clear masses from the Kennebec cut to 12 inch cubes and other of smaller sizes. The temperature of the room and of the ice were taken, the latter by boring into the block and imbedding a thermometer. The blocks were formed into cubes by careful sawing and rubbing on stone, much difficulty being encountered in forming plane surfaces for the reason that the saw, however carefully guided, was inclined to cut warped surfaces. Small blocks of white pine were interposed between the upper and lower surfaces of the press to equalize the distribution of the pressure. It was found that when subjected to pressure from whatever direction, the ice almost invariably resolved itself into small vertical columns, which, when the pressure was continued, buckled slightly and compressed, until in several cases, under a further increase of pressure, the block exploded with a loud report—this, however, only in the case of the better and more compact specimens. By vertical column is meant a column normal to the natural surface of the ice.

The results of the tests are given in the accompanying table, in which several specimens—18 in number—are tabulated with

their characteristics and the results. These show that at from 23 up to 300 lbs. there were evidences of yielding, and that the blocks were crushed at pressure varying from 100 up to 1,000 lbs. per square inch, with an average of about 575 lbs.

It was evident from the varying results shown in the table, that the temperature and condition of the ice and the original circumstances under which it was formed, had a very important bearing upon its capacity for resisting crushing; and it was my purpose to continue the investigation, making use of iron molds of exact form, in which the blocks could be frozen or compressed, and subsequently tested; but I was prevented from following this out by assignment to other duties.

As preliminary inferences to be drawn from these experiments, it may be said that the maximum pressure requisite to crush ice of the clearest and most compact structure, is 1,000 lbs. per square inch. That ordinary clear ice, such as we get from the upper Delaware River, would, under certain conditions, resist a pressure of 700 lbs., and that ice, in the condition that we should be likely to find it in the Delaware River at Liston's Point, would crush with 400 to 450 lbs. or less, from its gradual disintegration by exposure to sun, air and salt water.

Furthermore, that a certain degree of buckling or yielding through from one-half inch to one inch would take place before final crushing—this indicated elasticity being a valuable factor, as cushioning the blow by the mass of ice and affording time for the resistance of the structure exposed to it to be developed.

In the subsequent computations for the construction of the pier, 400 lbs. was therefore taken as the crushing datum, using in addition a factor of safety of three, which brought the resistance of the structure above the highest crushing pressure which could be developed in contact with it. The cylindrical form of the pile and the loose and floating condition of the ice in the lower Delaware, made this factor of safety ample.

It is evident from this paper that the investigation should be continued, and more exact and definite results be reached in regard to this important matter with which engineers in all Northern latitudes are compelled to contend. It is to be hoped that some one having the opportunity of doing this will devote some time and consideration to its further investigation.

EXPERIMENTS TO DETERMINE THE CRUSHING STRENGTH OF ICE, MADE AT FRANKFORD ARSENAL, PHILADELPHIA, FEBRUARY 14 AND 15, 1881, AND AT FORT TOMPKINS, STATEN ISLAND, FEBRUARY 22 AND 23 AND MARCH 2, 1881.

NOTE.—The testing machine at the Frankford Arsenal was not convenient to obtain the tests with the celerity demanded in testing so perishable a material as ice; the weights did not slide freely on the scale beam, and the beam took too heavy a weight to be handled quickly. The testing machine at Fort Tompkins had its loads indicated by hydraulic pressure ganges—one to 5,000 pounds, and the second 5,000 to 10,000 pounds.

Much difficulty was found in cutting the ice blocks for Tests I to IV, inclusive, with parallel and smooth faces. At Fort Tompkins, the bottom of a cake of ice was rubbed smooth on a level stone surface, from which surface perpendiculars were erected and the outline of the top surface was scribed one inch in depth all around. The block was then cut by a whip-saw, after which the unevenness was rubbed off on the stone bed.

Vertical means: Normal to natural surface of ice.

Number of experiment.	*Date.*	*Place of experimenting.*	*Nature of ice.*	*Temperatures.*			*Dimensions and weights.*		*Direction of applied pressure to the natural surface of ice.*	*Direction of columnar disintegration.*	*Weight at which the block yielded.*	*Pressure per square inch of yielding.*	*Weight at which the block crushed.*	*Pressure per square inch of crushing.*	*Compression between yielding and crushing.*	*Remarks.*
				External air.	*Room where tested.*	*Ice at time of testing.*	*Dimensions.*	*Weight of piece.*								
	1881.			°F.	°F.	°F.	*Inches.*	*Lbs*			*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*In.*	
I	Feb. 14	Frankford.	Pond ice of poor quality.	31	55½	25	6½ cube.	9¾	Vertical. .	Vertical.	1,000	23	10,000	235	. . .	Ice full of impurities in original water. Block roughly cut for the purpose of accurate test. As the pressure was gradually increased the block resolved itself into small vertical columns, which buckled and compressed until crushing occurred.
II	Feb. 14	do.	do.	31	55½	25	6½ cube.	8½?	do.	do.	1,000	23	11,500	272	. . .	Same ice; difference of weight owing to imperfect cutting; columns formed same as in I.
III	Feb. 14	do	do.	31	55½	25	6½ cube.	9¾	Horizontal.	. . . . .	Small resistance.	.	. . . .	. . . .	Split	Crushed so quickly that the strain was not determined; must have had internal flaw, or else some corner of ice acting as a wedge.
IV	Feb 14	do.	do.	31	55½	25	6½ cube.	9?	do.	Vertical.	2,000	47	4,000	94	None	Vertical columns, which separated, but did not compress.
V	Feb. 15.	do.	do.	32	68	25	6¼ cube	8⅜	Vertical . .	do	2,000	50	15,600	400	. . .	No remark.

Number of experiment.	Date.	Place of experimenting.	Nature of ice.	Temperatures. External air.	Temperatures. Room where tested.	Temperatures. Ice at time of testing.	Dimensions and weights. Dimensions.	Dimensions and weights. Weight of piece.	Direction of applied pressure to the natural surface of ice.	Direction of columnar disintegration.	Weight at which the block yielded.	Pressure per square inch of yielding.	Weight at which the block crushed.	Pressure per square inch of crushing.	Compression between yielding and crushing.	Remarks.
	1881.			°F.	°F.	°F.	Inches.	Lbs			Lbs.	Lbs	Lbs.	Lbs.	In.	
VI	Feb. 15.	Frankford.	Pond ice of poor quality.	32	68	25	6 cube.	7⅞	Vertical . .	Vertical.	2,000	55	. . . .	450	⅜	Vertical columns compressed or buckled, three-eighths of an inch the block crushed.
VII	Feb. 22.	Fort Tompkins.	Kennebec ice, very clear at first, but cloudy when tested.	. .	. .	. .	12 cube.	59	do.	do.	14,000	97	47,000 45,000	327	1	Ice clear at first, but the air being warmer veins formed in it, so that before the block was ready for testing it had a cloudy appearance. At 20,000 pounds began to divide into vertical columns; at 47,000. columns began to buckle, and pressure fell to 47,000, when, with one inch compressed, block crushed.
VIII	Feb. 22.	do.	do.	. .	. .	. .	6 cube.	. .	do.	do.	10,000	280	36,000 33,000	1,000	½	Block disintegrated into columns at 10,000 pounds; the columns stood 36,000; then with a falling pressure to 33,000, and, with ½ inch compressed, block crushed; strength greater than VII, probably because of more perfect cutting of block and of greater solidity of ice, being taken from centre of cake.
IX	Feb. 23.	do.	do.	36	36	31	12 cube.	57½	Horizontal.	do.	15,000	104	55,000	382	None	Columns in this case vertical; when the pressure became too great (55,000 pounds) the block crushed (or flew) with a report as of a pistol.
X	Feb. 23	do.	do.	36	36	31	6 cube.	7¼	do.	do.	3,000	80	36,000	1,000	do.	Resulted in same manner as larger piece IX.

XI	Feb. 23.	Fort Tompkins.	Very cloudy.	36	36	31	6 cube.	7¼	Horizontal.	Vertical.	2,000	55	33,000	917	. . .	Resulted same as preceding. Internal flaws more marked because of warmth of air.
XII	Feb. 23.	do.	do.	36	36	31	6 cube.	7¼	do.	. . . . .	1,000	28	25,000	700	None	No remark. The low pressure at which blocks XI, XII, and XIII crushed was owing either to imperfect cutting, allowing strain to come on single points, or to disintregration of the ice by heat; the blocks were very cloudy.
XIII	Feb. 23.	do.	do.	36	36	31	6 cube.	7¼	Vertical . .	Vertical.	1,000	28	25,000	700	. . .	Although subjected to vertical pressure, not able to determine any compression.
XIV	Mar. 2.	do.	Pond ice, 2 inches snow ice, rest clear.	31	29⅞	28⅞	10 cube.	33¼	do.	. . . . .	30,000	300	86,000	860	¼	It was found impossible to increase the pressure above 86,000 pounds, as the elasticity of the columns formed in the ice, and of the wood blocks used to equalize the strain, took up the movement of the machine. After crushing the ice-block one-quarter inch it was removed; and the temperature, taken by a thermometer inserted in an auger-hole, bored to the centre, gave 28 2-5 Fahrenheit.
XV	Mar. 2.	do.	do.	31	29⅞	28⅞	10 cube.	. .	Horizontal.	. . . . .	25,000	250	{ 60,000 67,000	600 670	⅛ ¼	{ No remark.
XVI	Mar. 2.	do.	3-inch layer of snow ice.	31	29⅞	28⅞	9x10x3	. .	do.	. . . . .	4,000	130	13,000	433	. . .	Pressure applied on 3 inches by 10 inches face; block very roughly cut; snow ice.
XVII	Mar. 2.	do.	2¾ inches of clear ice.	31	29⅞	28⅞	7½x10x 2¾	. .	do.	. . . . .	4,000	194	17,000	825	. . .	Pressure applied on 2¾ inches by 7 inches face; block very roughly cut; very clear ice.
XVIII	Mar. 2.	do.	Same as XIV and XV.	31	29⅞	28⅞	9 cube.	24½	do.	. . . . .	12,000	148	39,000	481	. . .	The two faces in contact with machine were not parallel, and brought strain on corners, making the crushing pressure very low.

VIII.

THE POCAHONTAS MINE DISASTER.

By J. Godolphin Osborne, Member of the Club.

Read April 19th, 1884.

The March number of the "*Virginias*" (attached) contains a detailed description of the mine, together with map of Pocahontas, and a plan of the workings, all of which, having been gotten up from data furnished by the superintendent, Mr. W. A. Lathrop, is correct, and therefore any further *description* in this is unnecessary.

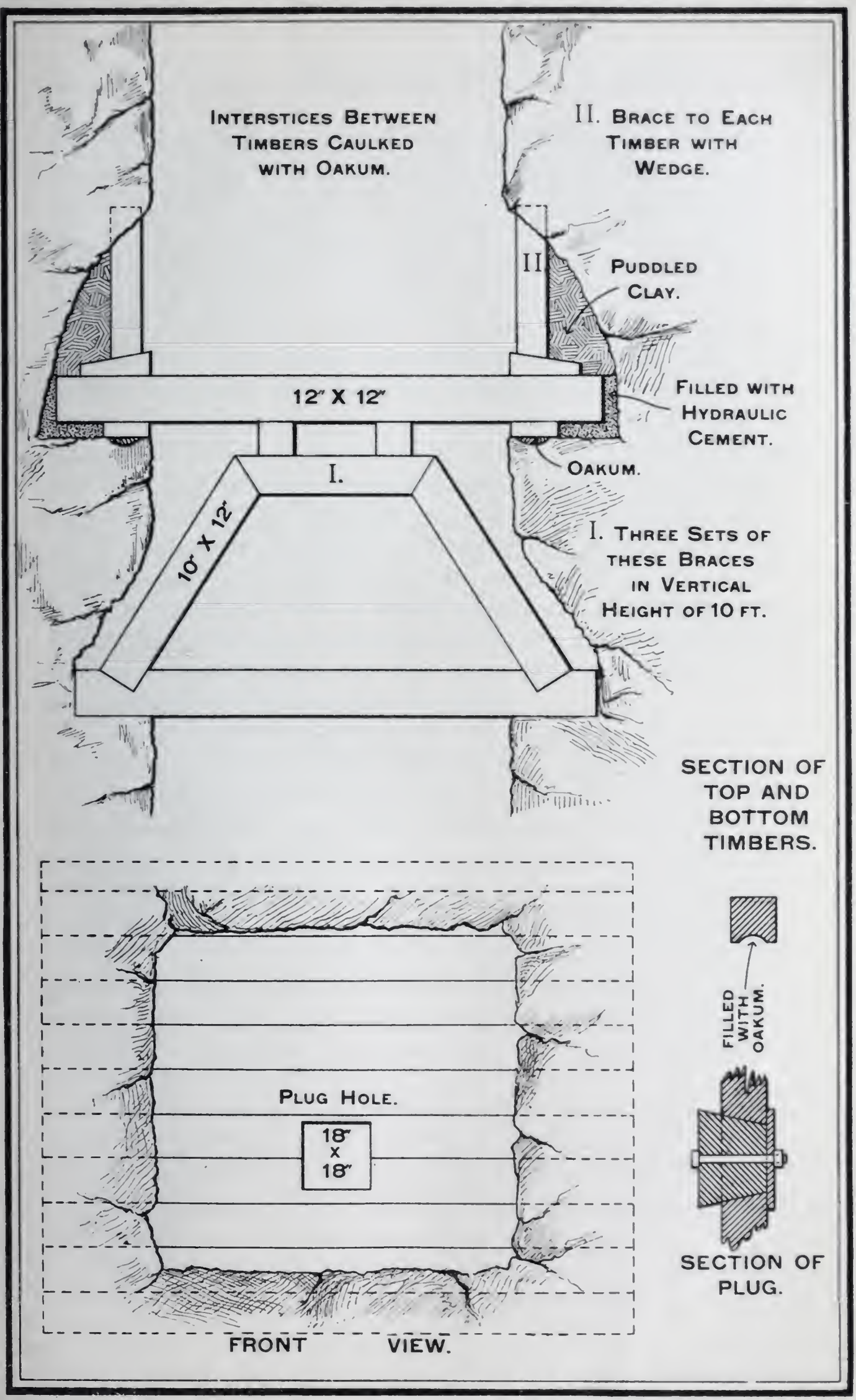
The 8 ft. Murphy fan, at the extreme western entrance, which is about 25 ft. higher in elevation than the main entrance, when run at about half speed, produced a strong current of fresh air throughout the entire mine, and no indications of foul air or gas had been noticed; had there been, the engineers in giving their "points," always in the roof, and working with a naked lamp as close to the latter as possible, must have detected it.

The loose coal having caught fire from the explosion, it became necessary to partially flood the mine before an entrance could be effected. After as close an examination as was possible, Mr. Lathrop decided that the fire was confined to the lower parts, near the entrances, the mine being on an up grade from the mouth of the main drift; this conclusion has since been proved correct.

The first step in the "flooding" was the erection of strong water-tight dams across each of the entrances and some little distance in to insure a good, compact and firm roof.

These dams are shown in the accompanying diagrams.

While these dams were in course of erection, preparations were made for putting down a drill hole from the surface to strike a point above the level expected to be reached by the water, to allow for the escape of air compressed by the inflow of water. The selection of this point was an easy matter, an accurate and detailed survey of the mine having been kept from the start. The point chosen was over the western end of Entry No. 3, north,


INTERSTICES BETWEEN TIMBERS CAULKED WITH OAKUM.
II. BRACE TO EACH TIMBER WITH WEDGE.
II
PUDDLED CLAY.
12" X 12"
FILLED WITH HYDRAULIC CEMENT.
OAKUM.
I.
10" X 12"
I. THREE SETS OF THESE BRACES IN VERTICAL HEIGHT OF 10 FT.
SECTION OF TOP AND BOTTOM TIMBERS.
FILLED WITH OAKUM.
PLUG HOLE.
18" X 18"
SECTION OF PLUG.
FRONT VIEW.

marked *A* on plan of mine in the "*Virginias*," and drilling, by an oil-well outfit, making a hole 5¾ inches diameter, commenced at 4 A.M. Saturday, April 5th. Work was kept up continuously, and on Tuesday, 8th, about 4 A.M., the drill broke through into the gangway, 135 ft. below, satisfactorily proving the correctness of the mine survey.

In the meantime a quantity of 6-inch pipe, which had been ordered from New Jersey immediately after the explosion, had arrived and been laid from the mouth of the "Fan Entry" up "Coal Run," that flows past the mine, about half a mile, the whole of it having to be carried by hand. This was completed, and the water running through it into the mine, in exactly two weeks from the time the pipe was ordered. In addition to this, water was thrown in through two 4-inch pipes from steam pumps, all the water being taken from "Coal Run."

It was calculated that it would take about 17,500,000 gallons to sufficiently fill the mine to drown the fire, and this was accomplished in sixteen days, one day being lost in repairing one of the dams, all the balance proving tight.

The flow of water into the mine was stopped on Monday, 7th, and the mine was emptied from the Main Entry by driving in the plug marked *B* in sketch of dam. All the dams were then taken down, and shortly afterwards the new fan (similar to the old one) and the engine to run it, the erection of which was begun immediately after the explosion, was completed and set in operation, and the removal of the bodies of the unfortunate victims (112 known) begun by a force of expert miners from Wilkesbarre, Pa., under Mr. W. Moody. This has been, as may be imagined, no easy task, as decomposition had set in to a very great extent and, all the brattice work having been blown out, the ventilation was not perfect.

No gas was met with, however, and the work has been successfully carried on, the bodies of 80 men and 6 of the mules having been brought out and buried up to this date, April 15th, 1884. About half of the bodies have thus far been identified, principally by articles of clothing or marks on the person.

The mine itself was very little damaged, and it is thought that mining can be resumed in from two to three weeks.

The cause of the explosion is, of course, only a matter of conjecture up to this time, but it is to be hoped that the mystery will be solved satisfactorily in the near future, after the mine has been carefully examined.

I would like particularly to call attention to the third paragraph, page 49, of the March number of the "*Virginias*," which gives the correct version of the condition of things at Pocahontas after the disaster, notwithstanding the ridiculous and purely imaginary statements published in the press of the country at the time of and after the explosion.

DISCUSSION.

By E. S. Hutchinson, Member of the Club.

Mr. E. S. Hutchinson supplemented the above by an account of his recent visit to the mine, confirming, as far as he had observed, Mr. Osborne's opinion of damage to the mine; timbers were displaced, cars demolished, etc., but there were no extensive falls of roof except in the fan-entry, where much slate had fallen, but where a week's work would repair damage. He attributes the safety of the roof to the fact that from 12″ to 18″ of coal had been left as an elastic support to the treacherous slate above. He considers the presence of five or six inches of fine, dry coal dust on the floor a phenomenon of special interest, and, while withholding a positive opinion in view of pending investigations by a Committee of the Am. Soc. Min. Engrs., he refers to a number of authorities to show the important bearing the presence of dust has upon explosions in mines, like this, apparently entirely free from fire-damp.

DISCUSSION OF FORMULÆ FOR TURNOUTS AND CROSSINGS.

By J. H. Murphy and the author, John Marston, Members of the Club.

By J. H. Murphy.

Read April 19th, 1884.

Referring to the article "Formulæ for Turnouts and Crossing," by Mr. John Marston (Proc., Vol. III, No. 5, p. 307, and Ref. Book, p. 3), I think he is somewhat in error. He makes the letter "A" = distance from heel of switch to toe of frog, g = gauge of track and n = No. of frog—and gives the equation $A = 2\ gn$ Now making $g = 4'\ 9''$ and $n = 8$, we have $A = 76$. Mr. Marston certainly cannot mean that he would put in a switch with a lead of 76 feet between the *heel* of the switch and the toe of a No. 8 frog. If he should apply this rule to the Lorenz or "Point" switch, and read from *point* of switch instead of *heel*, this distance of 76 feet will give very excellent results, or the lead can be reduced to 70 feet and a good line still obtained.

Again he makes "X" = distance between two frogs of a crossing and "d" = distance between tracks (*i.e.*, between gauge lines), and gives the equation $X = n\ (d - g) - \frac{d + g}{4\ n}$. If Mr. Marston would cut off the last part of the equation $\frac{d + g}{4\ n}$, he will find that he can get the very best results with $X = n\ (d - g)$. For a distance of $7'\ 5''$ between gauge lines, which is now very generally used, the equation gives $X = 21'\ 4''$, which cannot be improved on to give perfect line under the proper conditions.

I have written the above in answer to your request for a notice of any errors that may be discovered among these contributions, and would be very glad to hear from Mr. Marston on the subject.

I notice that he applies his reasonings to the old fashioned "stub" switch, which is now being rapidly done away with, and gives a sketch of a three-throw stub switch, the most dangerous invention now in track. Referring to this matter of three-throw stubs, I hope soon to present a sketch and explanation of a set of switches designed to do away with just such a three-throw switch

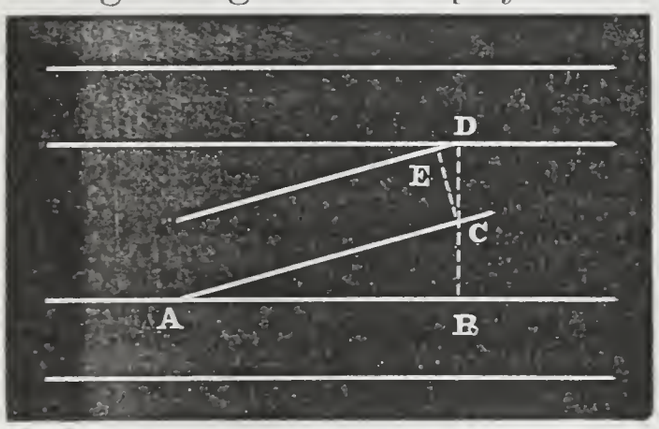
as is shown, and which I recently put in successful operation at Columbia.

By John Marston, Member of the Club.

Read June 21st, 1884.

I admit that the wording of the formulæ was made to apply to stub switches, as the sketch accompanying plainly showed, but, at the same time, that was not intended as an argument either for or against any particular style of switch, but were merely applied to the stub switch as being still the most common in use, and, in fact, unless the Pennsylvania Railroad management has changed its ideas in the last few years, is the only kind allowed on that road when "facing" switches have to be used. But if, by the use of any other kind of switch, the switch-rails are pivoted at the opposite ends, and what is usually the "heel" is called the "toe," it is an easy matter to alter the wording to correspond. I think, however, it is a mistake to have different names for the same part of the switch as tending to cause confusion, even when, by a change in mechanical construction, the original significance of the term is lost. I would, therefore, still call the end of the switch-rail farthest from the frog the heel, whether stub or split switches are used. I might add that the wording in the formulæ agrees with Messrs. Shunk and Trautwine, in the last editions of their works on the subject.

Regarding Mr. Murphy's second point, I must beg leave to differ with him, and think the following demonstration will show the formula for X is nearer right than he is. The exact distance AB between the points of two crossing frogs is equal to $\frac{BC}{\text{tang. frog angle}}$.



$BC = BD - DC$, and $DC = \frac{EC}{\text{cos. frog angle}}$.

But $BD = d =$ distance between tracks, and $EC = g =$ gauge

Therefore $AB = \frac{d - \frac{g}{\text{cos. frog angle}}}{\text{tang. frog angle}}$

Applying this formula to the case cited by Mr. Murphy, with $g = 4' 9''$, $d = 7' 5''$ and frog angle 7° 10′ (No. 8) gives $AB = 20' 10\frac{5}{8}''$ instead of 21′ 4″, according to Mr. Murphy's rule. The formula he criticizes makes it 20′ 11½″. Perhaps crossing frogs laid by Mr. Murphy's rule would be so nearly right as to make no practical difference in their working, but the formula is nearer correct as it is.

Mr. Murphy has had more experience with track than I have, but these formulæ were furnished me by one who now occupies a well-advanced position on the Pennsylvania Railroad, and who used them on the same part of the track where Mr. Murphy is now engaged.

In conclusion, as I am always anxious to be informed on all new devices in railroad work that are successfully in use, I hope to see in the next "Proceedings" a plan of Mr. Murphy's substitute for the three-throw stub switch.

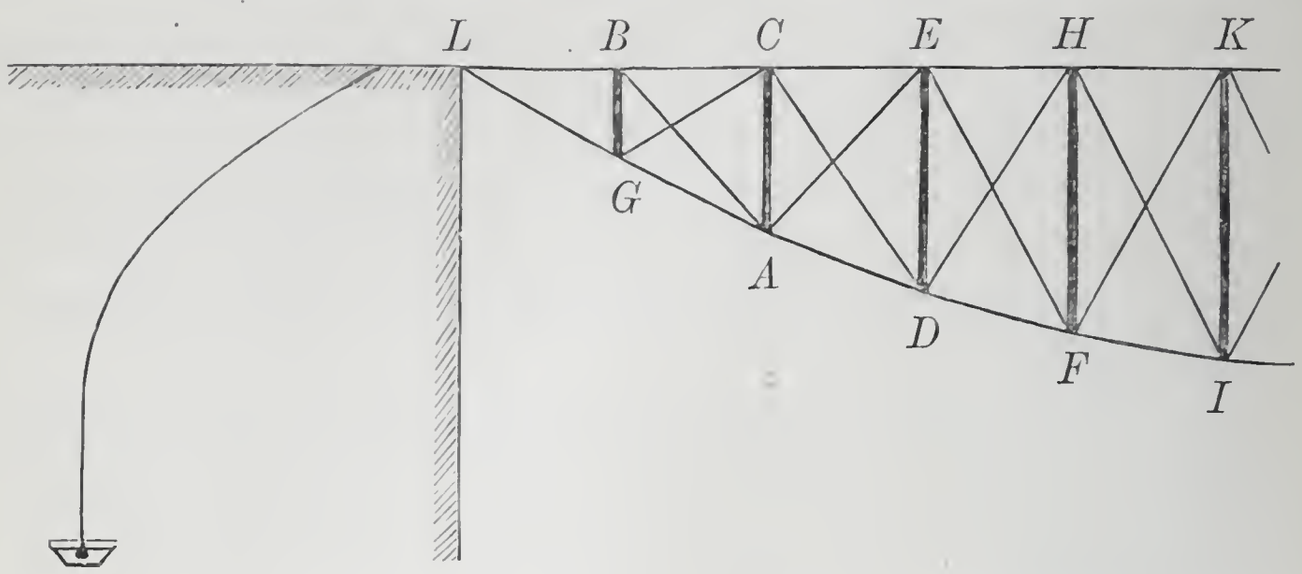
IX.

ON AN ECONOMICAL FORM OF BRIDGE TRUSS.

By Thomas M. Cleemann, Member of the Club.

Read May 3d, 1884.

In examining the amount of material in the different parts of an ordinary bridge, one is struck by the excess of weight of the parts in compression over those in tension, of course due to the fact of the additional amount of material required to resist bending in the former above what is indicated by the maximum stress per square inch. If the compression parts can be reduced in number, there results a corresponding saving in the iron required in the structure. The suspension bridge owes its economy to its having the principal part in tension only, but it is necessary to stiffen it, either by an auxilliary truss or by stiffening the chains within themselves, neither method being very satisfactory. An old style of bridge, of which several were erected in this vicinity some twenty years ago by the late Mr. John W. Murphy, is the inverted bow-string.



The portion L, G, A, D, etc., has its angles in a parabola, and, when uniformly loaded, the diagonals, of course, experience no stress. The chord LK, however, then sustains its greatest load, which is compression transmitted from the curved part. If we now conceive the points L and the corresponding opposite end to be anchored to the abutments, the latter would take the stresses transmitted from the arch, and the chord could be removed without affecting the stability of the bridge. For a variable load, however, it would still be required. If there were a load placed only at A, it would be sustained by the ties BA and EA, and, in the ordinary bridge, these stresses would be resolved at B and E into compression on BC and BG, EC and ED. If, however, BC and EC will not take compression, and the pieces LB and EH are formed to take tension, and are so connected to the adjacent pieces as to transmit it to anchorages at the abutments, we do away with the necessity of having a stiff chord, and the only parts in the bridge which have to sustain compression are the posts. We thus avoid the necessity of having the bridge carry as dead weight the amount required to stiffen the chord, and, although a sufficient dead weight must be put at the abutments to resist the pull of the chord and arch, it can often be more economically obtained there with masonry than with iron in the truss.

The following are the stresses in the proposed form of bridge:

Let W = the uniform load on one panel.

" W' = " variable " " "

" S = " span.

Let h = the depth of the truss at the middle of the span.
" n = " number of panels, supposed to be even.

Then maximum tension in $AB = \frac{W'S}{8h} \frac{AB}{BC}$

" $CD = \frac{W'S}{8h} \frac{DC}{BC}$

" $EF = \frac{W'S}{8h} \frac{EF}{BC}$

etc. etc.

Maximum compression in $BG = W + W'$

" $AC = \frac{W'S}{8h} \frac{DE}{BC} + \frac{3}{n} W' + W$

" $DE = \frac{W'S}{8h} \frac{FH}{BC} + \frac{4}{n} W' + W$

" $FH = \frac{W'S}{8h} \frac{IK}{BC} + \frac{5}{n} W' + W$

etc. etc.

Maximum tension in LB, BC, CE, EH, etc., $= \frac{W'S}{8h} n$

" $LG = \frac{(W + W')S}{8h} \frac{LG}{BL} n$

" $GA = \frac{(W + W')S}{8h} \frac{GA}{BL} n$

etc. etc.

To illustrate the theory advanced a little model has been made, with string fastened to two tacks in a drawing board, and with posts made of wooden knitting needles. It has eight panels, each three inches long, with a height at the centre of about one-fourth the span. The string of which it is composed breaks with about five and a half pounds. By the formulas the model will then sustain one and a half pound at each panel. These bags contain weights, each one pound, as it is not desired to break it immediately. It will be seen that it bears this load, amounting to two-thirds its breaking weight, or a total of seven pounds on the whole. Four pounds or less, added at the middle, ought to break it, and after the gentlemen have examined it sufficiently, this experiment will be made as a check on the calculations.

One of the principal advantages of this form of truss is its facility of erection without false works. It seems, too, to be espe-

cially adapted for military purposes on account of its easy transportation; the arch, chord and braces can be all composed of rope, and the compression parts of wooden poles, easily packed.

In a former paper the most economical height for a bridge over the Ohio of 515 feet span was calculated, and its weight. By using the same data for a bridge of this suspended plan, calculating its most economical height, it is found to contain only about five-sixths as much metal, excluding the amount required in the anchorage. This could be still further reduced by stiffening the posts. After loading each panel point of the model with a pound weight, two pounds were added at the middle, and, after a little time, two pounds more. It hesitated an instant, and then broke at each abutment, both arch and chord, and fell to the ground.

SOME PROPERTIES OF NUMBERS.

Wm. G. Neilson, May 17th, 1884.

The difference of the **SQUARES** of numbers that differ by unity = the sum of the numbers.

$$a^2 - (a-1)^2 = 2a - 1 = a + (a-1)$$

Examples: 2 and 3. $2^2 = 4$, $3^2 = 9$; $9 - 4 = 5 = 2 + 3$.

99 and 100. $99^2 = 9{,}801$, $100^2 = 10{,}000$;

$$10000 - 9801 = 199 = 99 + 100.$$

The difference of the **SQUARES** of numbers = the sum of the numbers multiplied by their difference.

$$a^2 - b^2 = (a+b)\ (a-b)$$

Example: 4 and 10. $4^2 = 16$, $10^2 = 100$; $100 - 16 = 84 = (4 + 10)\ 6$.

The difference of the **CUBES** of numbers that differ by unity = the sum of the squares of the numbers + the product of the numbers.

$$a^3 - (a-1)^3 = a^2 + (a-1)^2 + a\,(a-1)$$

Example: 3 and 4. $3^3 = 27$, $4^3 = 64$; $64 - 27 = 37 = 9 + 16 + (3 \times 4)$.

The difference of the **CUBES** of numbers = the sum of the squares of the numbers + the product of the numbers, and the result multiplied by the difference of the numbers.

$$a^3 - b^3 = (a^2 + b^2 + ab)\ (a-b)$$

Example: 3 and 20. $3^3 = 27$, $20^3 = 8000$; $8000 - 27 = 7973 = [9 + 400 + (3 \times 20)]\,17 = 469 \times 17 = 7973$

ON FINDING THE TRUE MERIDIAN.

W. S. Chaplin, March 1st, 1884

Many American text-books on land surveying contain descriptions of a method of finding the true meridian by observing the instant at which the pole-star and Alioth come into the same vertical, and then following the pole-star for a *certain time*, at the expiration of which the pole-star is said to be on the meridian. The time given in all cases is, I believe, incorrect. This time depends on the latitude of the place; it can be calculated as follows:

Let Z be the zenith of the place of observation.

A " Alioth.

S " pole-star.

P " the north pole.

In the triangle APS, AP, SP and the angle APS, are given by the nautical almanac. PC, an arc of a great circle perpendicular to AS, can be found from the triangle APS, as can the angle CPS; and then the angle SPZ, which, reduced to time, gives the time which *elapses* after the two stars come into the same vertical before the pole-star reaches the meridian. I have taken mean values of the right ascensions and declinations of the pole-star and Alioth, and calculated the time for various latitudes as follows:

LATITUDE.	M.	S.
40	25	36
50	25	24
60	25	5
70	24	29

This method would not be available down to 30° latitude, as Alioth would not be visible at its lower culmination.

SPRING OF RAILS, CHORD 10 FEET LONG.

EDW. SAMUEL, May 18th, 1884.

Radius in Feet.	Rise in Inches.	Radius in Feet.	Rise in Inches.
20	7.62	65	2.30
22.5	6.76	67.5	2.22
25	6.06	70	2.14
27.5	5.50	72.5	2.06
30	5.04	75	1.99
32.5	4.66	77.5	1.93
33	4.57	80	1.87
35	4.32	82.5	1.81
37.5	4.02	85	1.76
38	3.96	87.5	1.71
40	3.76	90	1.67
42.5	3.54	92.5	1.62
45	3.34	95	1.58
47.5	3.16	97.5	1.54
50	3.00	100	1.50
52.5	2.86	120	1.25
55	2.74	150	1.00
57.5	2.62	200	.75
60	2.50	250	.60
62.5	2.39	300	.50

WHEEL BASES FOR TURNTABLES, 4′ 3″ DIAMETER.

EDW. SAMUEL, MAY 18th, 1884.

Gauge in Inches.	Length of Maximum Wheel Base in Inches.	Gauge in Inches.	Length of Maximum Wheel Base in Inches.
16	48.42	27	43.27
17	48.08	28	42.63
18	47.56	29	41.95
19	47.33	30	41.24
20	46.91	31	40.5
21	46.48	32	39.71
22	46.01	33	38.88
23	45.52	34	38.01
24	45.	35	37.09
25	44.41	36	36.12
26	43.87		

NOTES AND COMMUNICATIONS.

THE EXHAUST INJECTOR.

Regular Meeting, February 16th 1884.—Mr. Edwin Ludlow presented the following:—

A patent was obtained for this injector in England, in 1880, by Hamer, Metcalf & Davies. The first of them that I ever saw was a few months ago, when we bought a No. 7 of this type to feed three 34-inch boilers 30 feet long, generating steam for a 40 H. P. stationary engine, used to hoist coal and run the machinery in the breaker at the Hickory Swamp Colliery.

The engine has a 3-inch steam pipe and a 5-inch exhaust. A 3-inch opening was tapped into the exhaust pipe near the cylinder, to which the injector was attached.

The exhaust pipe was left with the same opening as before, so that the exhaust could pass to the outer air as free and unfettered as ever.

To set the injector to work communication is simply made with the exhaust and the feed water—the water tank being placed slightly above the injector. The exhaust enters the top of the injector and passes into a conical nozzle having within it a fixed conical spindle, the object of which is to concentrate and direct the flowing exhaust into a circular jet by the time it meets the cold feed water and thus precipitates condensation.

The cold water enters at the side of the injector near the top, and surrounds the steam passing through the conical chamber, thus commencing the action of condensation at once.

The exhaust and water meet in the condensing chamber, which forms the upper part of the hinged nozzle. This hinged nozzle is very important, and, in fact, imparts to the injector its automatic action. When not working the nozzle hangs back, allowing ample space for the water and steam to meet. When the meeting has taken place, condensation being instantaneous, a partial vacuum is formed and the hinged nozzle is drawn from its lying back position, contracting the space through which the combined exhaust and water have to pass.

The whole inward construction is eminently adapted for instantaneous condensation, forming a fairly good vacuum. We all know the enormous velocity with which steam will rush into an imperfect vacuum, and the momentum consequent on this high velocity enables the liquid lines into which the water and exhaust have been formed to pierce quite high pressures.

We have never been able to get the injector to work when the boiler pressure exceeded 70 pounds, but for all pressures below that it gives perfect satisfaction.

It takes the feed water at a temperature very little above freezing, and delivers it to the boilers at about 140° Fah.

Having had no opportunities as yet for making any careful experiments myself, I take the liberty of quoting Mr. C. M. Percy, of Wigan, England:

"Experiments were made with what is known as a No. 12 exhaust injector, which proved, among other things, that the minimum increase in temperature imparted to the feed water by passing through the injector is 100° Fah., and if more than this heat is added there will be less saving in water.

"No. 1 experiment showed that with feed water at 60° Fah., 2,490 gallons per hour were taken from the tank and 2,736 gallons per hour were delivered into the boilers at a temperature of 160°. This gives increased temperature 100°, and saving of water 246 gallons per hour. The number of heat units saved per hour being $2490 \times 10 \times 100 = 2{,}490{,}000$.

"No. 2 experiment took feed water from the tank at the same temperature 68°, the quantity being 2,280 gallons per hour, and the quantity delivered into the boiler was 2,561½ gallons per hour at a temperature of 190°. The increase in temperature is 122°, the saving in water 281½ gallons per hour, the heat units saved being 3,125,030. That is, we simply reckon one heat unit as being the heat required to raise the temperature of one pound of water one degree, and each gallon of water is ten pounds."

The exhaust injector is pumping engine and heater combined, and needs no live steam. It allows the heavy and impure exhaust to pass on, and snatches for its own use only that which is lighter and purer. It is claimed that it can be used for all kinds of engines whether working continuously or only for a few minutes at a time.

POWERS' DISINFECTING TANK AND AUTOMATIC SYPHON, FOR THE DISPOSAL OF SEWAGE OF COUNTRY HOUSES AND HOTELS.

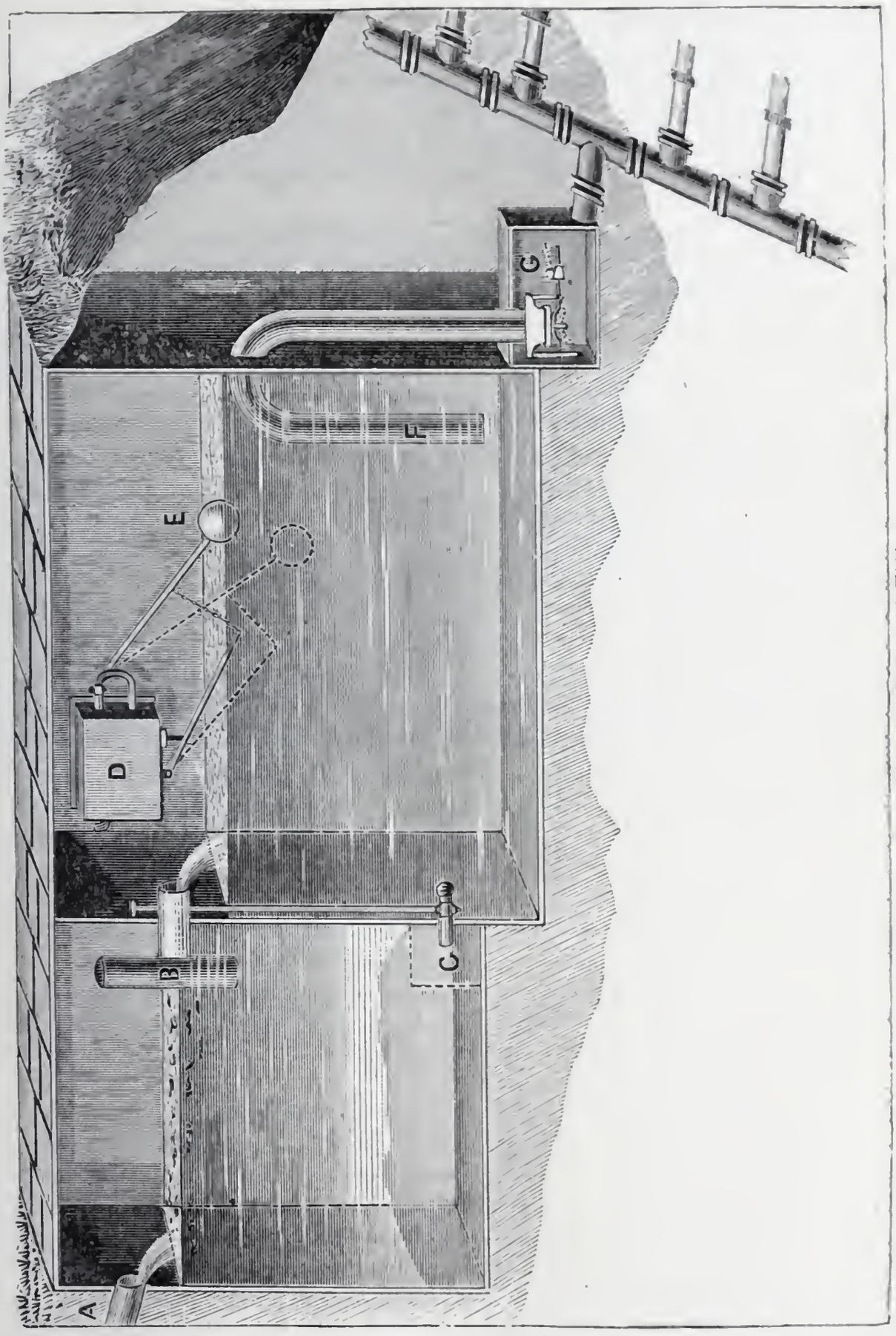
Regular Meeting, April 5th, 1884.—The object of this tank is: first, the separation of the solid and liquid portions of the sewage; second, the disinfection of the liquid portion and precipitation of the matter held in suspension; third, the automatic discharge of the liquids at intervals more or less frequent, and lastly, the removal of the solids.

The tanks are usually built of brick and cement, and are divided into two compartments, the first for the interception of the solids, and the other for the chemical treatment and discharge of the liquids.

These compartments are connected through a pipe "B," the inlet to which is so situated that only the liquids with the matter held in suspension can pass into the second or discharge tank, both the floating matter and the heavier solids remaining in the intercepting tank. In the discharge tank there is a chamber "D," containing sufficient perchloride of iron to thoroughly disinfect the contents of the tank previous to their discharge. This chamber is connected with a reservoir "O," containing sufficient of the disinfecting liquid for from 40 to 50 charges.

The float "E," operates two valves, one cutting off communication with the reservoir, and the other allowing the contents of "D" to be discharged into the tank. The action of this float takes place some time before the liquids have attained sufficient height to operate the syphon "F," so that there is ample time for the disinfecting liquid to become well mixed with the contents of the tank and precipitate the matter held in suspension.

The outlet of the syphon "F," is closed by a weighted valve "G," until the pressure is sufficient to overcome the weight, when the syphon begins to operate, and the tank is emptied in a few minutes through the tiles, which may be used for subsoil irrigation or discharged into a neighboring stream, the intervals between the discharges



SECTIONAL VIEW.

being governed by the size of the tank and amount of sewage. It is sufficient, however, to admit of the purification of the ground or stream and prevent saturation.

The last operation, the removal of the solids, occurring in an ordinary residence occupied during the summer, but once in the year, is accompiished after the family

have left, so that there is not the slightest inconvenience from this cause, nor need there be even when the house is occupied.

The operation is performed by the draining off of the liquids through the cocks "CC," the cover is then removed, the contents mixed with calcined gypsum and powdered charcoal or sawdust, when it assumes about the consistency of peat, and with a long-handled shovel can be cut into cakes, and deposited on the manure heap for use in fertilizing.

This device is used at the Brighton Hotel, Manhattan and Oriental Hotels, at Manhattan Beach, the Argyle Hotel and Cottages at Babylon, L. I., and at many private summer residences on Long Island, giving everywhere entire satisfaction.

WOODEN WATER PIPE.

Regular Meeting, May 3d, 1884.—Mr. C. Henry Roney exhibited a section of 4-inch Wooden Water Pipe and Joint found about two feet below the surface while excavating a trench for the conduit of the Philadelphia Sectional Electric Underground Company on Chestnut street, between Fourth and Fifth, and described those which had been found on Chestnut and Market streets during the progress of the work. These are interesting as showing the durability of such pipes and connections under the conditions to which they had been subjected.

The section shown was of spruce, originally about 14 inches in diameter at the large end and somewhat smaller at the other, having a wrought-iron band about $1\frac{1}{2}$ inches wide, $\frac{3}{8}$ inch thick at one side and tapering to a thin edge at the other, so that it could be driven on or into the end of the log near the outer circumference; a piece of iron pipe 4 inches internal diameter and about 12 inches long, tapered to a thin edge at each end, served to connect the ends of two adjoining logs, which were driven over it end to end, and prevented from splitting by the iron bands around the ends of the logs. In some cases no interior iron coupling pipe was used; one log was tapered at the end and driven into the next one which was prevented from splitting by the exterior iron band.

The 4-inch pipes, so far found, were of yellow pine, spruce and oak, of about 12-foot lengths, and from 12 to 24 inches in diameter, and supposed to have been laid between 1795 and 1805; the depths at which they were found varied from two to eight feet below the surface of the street.

The outer bark and heart wood of the spruce logs were generally sound, while the inner bark and sapwood were decayed, except where the soil was dry, gravelly or porous, when the greater part of the wood was decayed and the iron badly corroded. A specimen of red oak from a log adjoining the spruce one shown was decayed on the under side, but other portions looked nearly as fresh as if recently laid, the portions in contact with the iron coupling and band were blue-black from the action of the tannic and gallic acids on the iron. The 6-inch pipes were much larger, in some cases nearly 30 inches external diameter; in most instances the iron couplings and bands were but slightly corroded, the amount of corrosion seemed, however, to depend very much upon the character of the soil in which they were found—where the wood was decayed, the iron seemed to have rusted more than where the wood was well preserved from access of air and probably from the same causes. In some

instances where the logs were of very large diameter, they had been reduced at the ends to fit the bands, but in most cases the bands were driven into the ends of the logs without any reduction of diameter. Where exposed to the action of leaky gas pipes, the wood was blackened by it and very offensive in odor; in other cases no unpleasant odor was perceptible upon removal of the wood from the soil.

POPE'S "BRIDGE ARCHITECTURE."

Regular Meeting, May 17th, 1884.—Howard Murphy, Esq., Secretary and Treasurer Engineers' Club of Philadelphia, Dear Sir: I herewith present you, for the Club, an interesting work on "Bridge Architecture," printed in the year 1811. It contains a description of "Pope's Flying Pendant Lever Bridge," which was the plan proposed about that time for spanning the Hudson River. An interesting article on the "Schuylkill River Bridge" that was completed about the time this book appeared, is one of particular interest to those members of the Club who reside in Philadelphia. It speaks of it as "the permanent bridge lately erected over the Schuylkill River." It would be interesting to know how long since it ceased to be permanent. If I had the time it would afford me great pleasure to present a paper of comparison of the bridges in the early part of this century with those of to-day. I have not the time, but trust some other member of the Club will take the subject up.

The idea of utilizing the approaches of the East River Bridge for storage warehouses, etc., is not original, since T. Pope purposed doing the same thing with his Flying Pendant Bridge seventy-three years ago. Respectfully submitted, Saml. Rea.

ABSTRACT OF MINUTES OF MEETINGS.

Of the Club.

March 1st, 1884.—Regular Meeting.—President Wm. Ludlow in the chair; 34 Members and 8 Visitors present.

President Ludlow described tests of the Crushing Strength of Ice.

The Secretary exhibited, for Mr. C. A. Ashburner, a set of blues of some yet unpublished details of the Chicago Cable Railways.

The Secretary presented a note, by Prof. W. S. Chaplin, upon a prevalent error in data given for Determining the True Meridian.

Mr. C. J. Quetil, visitor, exhibited models of the Wire Truss recently described by him.

Prof. Mansfield Merriman presented a statement of the progress of the Triangulation carried on in Pennsylvania by the United States Coast and Geodetic Survey, and exhibited a map showing its present condition. The stations located are twenty-seven in number, of which nineteen have been occupied for the measurement of angles. These are in the southeastern part of the State, in the counties of Bucks, Montgomery, Delaware, Chester, Lancaster, York, Dauphin, Lebanon, Berks, Lehigh, Northampton, Monroe, Carbon and Schuylkill. The geographical positions of the stations have been computed from two of the sides of the primary coast triangulation, one near Elkton, Maryland, and the other near Trenton, New Jersey, which serve as bases for the work thus far executed.

The Secretary announced the receipt of the following contributions to the library from two very good friends of the Club: from Genl. Wm. F. Raynolds, several hundred valuable Reports, Documents and Maps; and from Mr. Thos. L. Lüders a handsome framed photograph of the New Public Buildings at Brussels.

Mr. John T. Boyd informally presented the following for consideration prior to their intended formal presentation at the next Business Meeting:

Resolved, That on and after the fifteenth day of March, 1884, all papers, descriptions, illustrations or explanations upon sub-

jects of interest presented by the Committee on Information, or by invitation from the Club, be and are hereby allowed to occupy or take up twenty (20) minutes only of the time of any Club meeting, unless otherwise requested by a majority of the members then present at said meeting.

Resolved, That any papers, etc., as above, requiring a longer time than the said twenty (20) minutes for their completion, may be continued at the next meeting following the one at which they are first presented.

Resolved, That this rule shall not apply to the discussion following the reading to completion of any paper, etc , as above.

Resolved, That the Secretary be and is hereby directed to print these resolutions in the next notices sent to all members, should the same meet the approval of the Club.

March 15th, 1884.—Special Business Meeting.—President Wm. Ludlow in the chair; about 35 Members and 5 Visitors present.

The Board of Directors presented, as their Report, their minutes since last Business Meeting of the Club. The Resolutions noted in abstract of March 1st meeting were unanimously adopted.

The resignations from Active Membership of Messrs. Jesse Lightfoot and C. B. Richards were read and accepted.

The following gentlemen were elected Active Members of the Club: Messrs. Kenneth Allen, J. M. Rüdiger, Jr., Frederic C. Wootten, Edw. H. Barnes, Walter D. Heston, Robt. W. Lesley, Wm. Paul Gerhard, Jesse T. Vogdes, Jos. J. McKee, P. A. Taylor, Wm. Wharton, Jr., F. A. Dean, De Courcy May, Jas. Rowbottom, V. E. Briand de Morainville, Richd. W. Jones, Augustus Dietz, Wm. H. Millard, James Christie, H. G. Stewart, W. A. Parry, Theo. J. Lewis, E. R. Wallace and B. K. Field.

Messrs. Frederic Graff, Chairman, Jos. N. Du Barry, James Worrall, James R. McClure and John H. Dye, the Committee appointed to prepare the Memorial of our late Past President, Mr. Strickland Kneass, presented the result of their sad but earnest work, in a comprehensive review of the professional career and labors of the Engineer, and a sincere tribute to the personal life of the Christian Gentleman.

Mr. Robt. P. Field presented a description of a method he had used to obtain formulæ for Switch Calculations.

Mr. C. Henry Ott presented an account of a recent Establishment of True Meridian in Philadelphia.

Mr. William Lorenz presented blues of the Steel Superstructure which he had discussed at a recent meeting.

Messrs. Young & Sons, Philadelphia, submitted sample of Stake Tacks. In the head of each is a concavity to admit point of rod. Thus another, although trifling, source of error may be eliminated, and the engineers' tacks may be more readily distinguished from others.

April 5th, 1884.—Regular Meeting.—Past President Henry G. Morris in the chair; 36 Members and 2 Visitors present.—Mr. Henry G. Morris exhibited, on behalf of Mr. Israel W. Morris, two ancient and curious works upon mining: "The Golden Treasury, or, the Complete Minor, being Royal Institutions or Proposals for Articles to Establish and Confirm Laws, Liberties and Customs of Silver and Gold Mines," by Thom. Houghton, London, 1699, and "A Collection of Scarce and Valuable Treatises upon Metals, Mines and Minerals," by James Hodges, London, 1740. The latter contains, *inter alia*, "How to know the Condition of the Earth by Taste;" "Of Juices, and first of Allum." "The Opinion that Quicksilver and Sulphur are the Matter whereof Metals are made, is defined." "How to know the ill Qualities that infect the Oar, and how to purge them away." "Wherein is showed how true and perfect Gold may be made by Art, with Loss to the Workman," etc.

Mr. Henry G. Morris gave a brief description of an Atmospheric Elevator, consisting of a closed cage or car working in an air tight well, the air pressure, supplied by a "Root" or other pressure blower, being admitted to the top or bottom of the cage, in descending or ascending. The doors at the different stories opening inwards, the pressure of air keeps them closed until the interior of the car is brought opposite, when the pressure being relieved, the door can be opened into the car. The car being counterbalanced, only a comparatively slight pressure of air, equal to a water column of 6 to 8 inches only, is required to

move an average load on a car six feet square. The escape of air beneath the car being at all times readily controlled by the attendant, it is impossible for the car to descend at a dangerous speed, and other obvious features render this form of elevator comparatively safe.

Mr. Henry G. Morris also exhibited a sample of Seamless Copper Tube which had been compressed endwise under a steam hammer, and showed peculiar foldings of the metal into overlapping equilateral triangles forming an interior hexagonal section. The absence of fractures showed great purity of material.

Mr. John T. Boyd described a new design for Parlor Cars for the Pennsylvania Railroad.

The Secretary presented, for Mr. Edward Parrish, an illustrated description of Powers' Disinfecting Tank and Automatic Syphon.

The Secretary presented, for the Reference Book, a table which he had prepared of Vulgar Fractions of 1 inch Reduced to *Exact* Decimals of 1 inch.

Mr. Wm. L. Simpson exhibited a remarkably perfect casting of a toad, the pattern used being the toad himself.

April 19th, 1884.—Special Business Meeting.—President Wm. Ludlow in the chair; 36 Members and 5 Visitors present.

The following gentlemen were elected Active Members of the Club: Messrs. W. Hunter, H. K. Nichols, Stewart L. Neff, Lloyd Bankson, Wm. B. Reilly, Jas. R. Schick, Jesse Garrett, Theo. H. Lüders, J. Chester Wilson, W. S. Sheafer, S. B. Whiting, Frederick V. Matton, Jno. W. Nute, Paul C. Brewer, H. W. Loss, Jones Wister, Geo. W. Bramwell, John S. Naylor and Sam'l R. Marshall.

Mr. S. N. Stewart, visitor, described a Cushioned Pier and Rolling Trunnion Drawbridge. With a working model he showed that a six pound draw could be turned by a pennyweight pressure or a breath, and claimed that, with a leverage six times as great as that of the model, twenty pounds pressure would turn a 100 ton draw. He also claims that a pivot-bridge, swinging in a horizontal plane, is a trap into which men, teams and railroad trains fall every year, while a Bascule draw, rising in the air, closes the approach and serves as a signal and warning. Refering to his project for a bridge across the Delaware, he said:

"Hitherto the restrictions imposed by the authorities have been practically prohibitive, but the land interests are as much to be considered as those of navigation, for rivers were not made for mariners alone; and the land interests are really greater than the interests of those who go down to the sea in ships. A compromise should be effected, for a bridge has already become a pressing need and will soon be a positive demand." Mr. Stewart claimed that a bridge only 20 feet wide would accommodate two continuous streams of vehicles and still leave a wide foot-way.

Mr. Wm. P. Osler presented, for Mr. J. Godolphin Osborne, an account of the Pocahontas Mine Disaster.

Mr. E. S. Hutchinson supplemented the above by an account of his recent visit to the mine.

Mr. J. Foster Crowell announced that the new bridge of the Pennsylvania Schuylkill Valley Railroad over the Schuylkill River at Manayunk had just been completed, and noted, as a remarkable illustration of the vast strides made in American bridge construction during the past few years, that so large and important a structure as this is, being one-third of a mile in length and 90 feet high, can be reared and come into use without exciting special interest or even deserving particular mention from an engineering point of view. There were, however, certain structural features, arising out of some peculiarities of location, which might prove instructive, and these were briefly described and illustrated by blackboard sketches.

On motion of the Secretary, Mr. Crowell was requested to prepare an illustrated paper upon this bridge for publication in the Proceedings.

The Secretary read, from Mr. J. H. Murphy, a discussion of the Switch Formulæ by Mr. John Marston, recently published, which was extended to a discussion of curve location by Messrs. J. F. Crowell, A. R. Roberts and the Secretary.

Mr. A. R. Roberts described a contrivance he had designed, by which a three-throw point switch can be operated from a single stand.

The Secretary read, for Prof. L. M. Haupt, a letter from Prof. Louis H. Barnard, urging an interest on the part of the Club in the election of Trustees of the State College, and it was referred

to the Secretary with instructions to confer with Prof. Haupt and report at next meeting.

The Secretary explained that the Reference Book sheets were all published in the Proceedings, and, in that form, were open to purchase by any non-member desiring them, but he considered that their *separate publication in note book form* should be exclusively for the benefit of Club Members, and offered a motion to that effect, which was carried.

Of the Board of Directors.

March 6th, 1884.—Special Meeting.—President Wm. Ludlow in the chair and the entire Board present. After discussion it was ordered that, hereafter applications for Active Membership shall be submitted to the Committee on Membership for general approval before they are read at a meeting or posted in the Club Rooms, and that they shall not be presented to meeting or posted until so approved by that Committee.

In case of non-approval of an application and of inquiry as to the same, the Secretary was directed to simply inform the inquirer that "the application has not been approved by the Committee on Membership."

The Secretary suggested that President Wm. Ludlow be requested to sit for his portrait for insertion in the Proceedings, which suggestion was unanimously adopted.

March 15th, 1884.—Regular and Adjourned Meeting.—President Wm. Ludlow in the chair and the full Board present.

The Finance Committee reported in favor of fixing the salary of the Secretary and Treasurer, for the year 1884, at one thousand dollars, and the President announced that the report was unanimously adopted. Communications were received from Mr. C. E. Billin with regard to the Club Receptions. Under date of March 12th, 1884, he reported a balance on hand from last reception of $99.99, and, under same date, he requested to be informed of the action of the Board with regard to the proposed Second Reception. The Secretary was directed to inform Mr. Billin that the Board

considered that hereafter receptions should not be held at intervals shorter than six months.

The Secretary was directed to carry out his suggestion to have the portrait of the late John C. Trautwine framed with his autograph letter accepting Honorary Membership.

A communication was presented by the Secretary from the Boston Society of Civil Engineers, inviting the Officers of the Club to be present at their Annual Dinner on March 19th, 1884. The Secretary was directed to acknowledge the invitation.

April 12th, 1884.—Special Meeting at the Club Rooms at 9 o'clock A.M.—President Wm. Ludlow in the chair and Messrs. Jones and Cleemann present.

The Secretary asked the opinion of the Board as to whether the 25 free author's copies of Proceedings should be given to authors of Reference Book contributions in the same, and he was directed to use his discretion in the matter.

The Secretary requested the Board to fix a price, to non-members, upon the large plate paper phototype portraits presented by the Club. One dollar each was fixed as the price.

CONTRIBUTIONS TO THE LIBRARY.

From March 1st to May 31st, 1884.

From the INSTITUTION OF CIVIL ENGINEERS, London, England.

Bramwell—Telephones.
Douglass—The New Eddystone Lighthouse.
Anderson—The Generation of Steam.
Newman—Cylinder Bridge Piers.
Preece—Electrical Conductors.
Anderson—The Alexander II Bridge.
Clausius—The Theory of the Dynamo-Electric Machine.
Fowler—Dredgers and Dredging on the Tees.
Cuppari—Water Raising Machines.
Dobson—Timaru Water Supply.
Faija—Mechanical Examination and Testing of Portland Cement.
Frecheville—Mining and Treatment of Gold Ores in the North of Japan.
Pilbrow—An Artesian Well at Bourn.
Ashhurst—Reconstruction of Bhim Tal Dam.
Coles—Pumping Hot Water.
Conder—Speed on Canals.
Hackney—Forms of Test Pieces.
Abstracts of Papers in Foreign Transactions and Periodicals. Vol. LXXV.

The following papers, issued prior to their exchange with the Club, have also been kindly contributed by the Institution:

Barlow—Existence (Practically) of the Line of Equal Horizontal Thrust in Arches. 1846.
Baldwin—Tunnel Construction. 1877.
Barton—Carlingford Lough & Greenore. 1876.
Bazalgette—The Sewage Question. 1877.
" —Embankments of the Thames. 1878.
Beaumont—Fracture of Railway Tires. 1876.
Bell—The Rajpootana (State) Railway. 1877.
I. L. Bell—Economy of Fuel in the Blast Furnace for Smelting Iron. 1872.
Bidder, Jr., and Chubb—Coal Breaking by Machinery. 1869.
Blood—A Skeleton Pontoon Bridge. 1878.
Bourne—Ships of War. 1867.
Braidwood—On the Means of Rendering Large Supplies of Water Available in Cases of Fire. 1844.
Braithwaite—The Rise and Fall of the River Wandle. 1862.
Bright—The Telegraph to India. 1866.
Culley, Sabine, Bontemps and Unwin—Pneumatic Transmission. 1876. 2 copies.
Samuda—Iron Plated Ships. 1864.
Samuelson—Blast Furnaces. 1871.
Shelford—Outfall of the River Humber. 1869.
Bainbridge—Kind-Chaudron System of Sinking Shafts Through Water Bearing Strata. 1872.
Andrews—The Use of Cellular Caissons. 1881.
Anstead—Lagoons and Marshes on the Shores of the Mediterranean. 1869.
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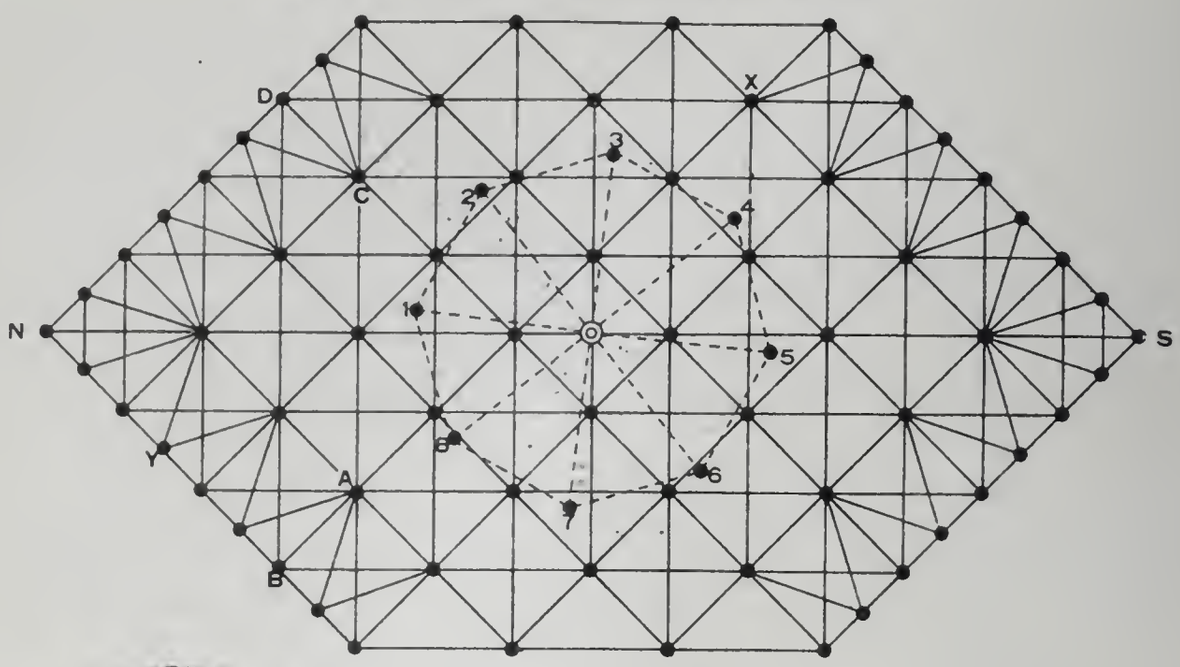
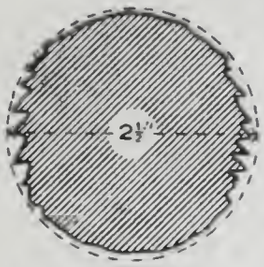
Jesse Lightfoot, March 15th, 1884.

C. B. Richards, " " "

DIAGRAM OF BRANDYWINE LIGHT HOUSE,

AT PLANE OF UPPER HORIZONTAL BRACES.





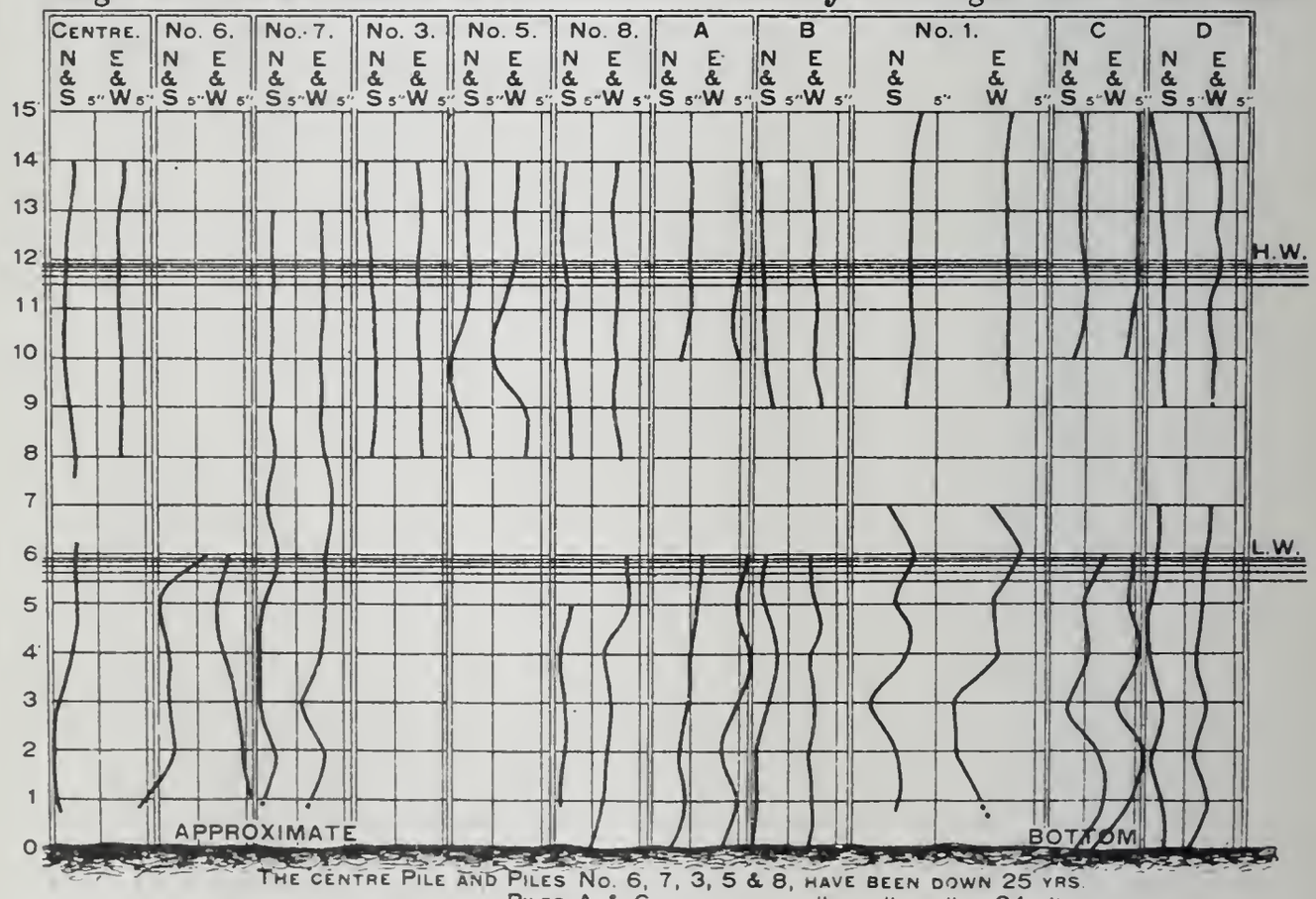
SUBMERGED 30 YEARS.

ORIGINAL DIAM., $2\frac{1}{2}$". DIAM. OF CIRCUMSCRIBING CIRCLE AFTER SUBMERSION, 2.38"

EXPOSED ABOVE SURFACE OF WATER 30 YEARS.

ORIGINAL DIAM. SUPPOSED TO HAVE BEEN $1\frac{3}{4}$"

Diagram of Measurement of Pile Shafts of Brandywine Light House Structure.



THE CENTRE PILE AND PILES No. 6, 7, 3, 5 & 8, HAVE BEEN DOWN 25 YRS.
PILES A & C, " " " 24 "
PILES B & D, " " " 16 OR 17 YRS.

DIRECTION OF EBB AND FLOOD CURRENTS ABOUT S. 35° E. & N. 25° W.
PILES A, B, C AND D, ARE ROLLED IRON; THE OTHERS ARE HAMMERED
THE FINE VERTICAL LINES CORRESPOND TO DIAMETERS OF 5 INS.
THE VARIATIONS (GENERALLY IN EXCESS) ARE SHOWN BY THE HEAVY WAVED LINES.
THE HORIZONTAL EXAGGERATION IS TWELVE FOLD.

FROM REPORT OF
LIEUT COL J. D. KURTZ
...
CAPT M. R. BROWN.

PROCEEDINGS
OF THE
ENGINEERS' CLUB OF PHILADELPHIA.
ORGANIZED DECEMBER 17th, 1877.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

NOTE.—The Club, as a body, is not responsible for the facts and opinions advanced in its publications.

Vol. IV.] AUGUST, 1884. [No. 3.

X.

EFFECT OF SEA WATER ON IRON, AS EXHIBITED AT BRANDYWINE LIGHTHOUSE, DELAWARE BAY.

By EDWARD PARRISH, Member of the Club.

Read May 17th, 1884.

THE Brandywine Lighthouse is situated on the shoal of that name, in the Delaware Bay, eight miles inside the Capes.

The house is founded on screw piles of hammered iron $5\frac{1}{2}$ inches in diameter, and provided with screws on the ends 3 feet in diameter. The shafts are inclined at an angle of about 85° to the horizon.

The house piles are nine in number; eight occupying the angles of an octagon and one in the centre. These are surrounded and protected by an ice fender, composed of fifty-two piles of rolled iron supplied with screws of the same diameter as those of the house piles, are driven vertically and were originally braced together with horizontal braces of round rolled iron $2\frac{1}{2}$ inches in diameter, near the levels of high and low water.

The plan of the ice fender is that of an elongated hexagon, the house occupying the centre.

The structure was originally placed in 6 feet of water at low tide, but the sand is shifting, and at times considerable scour

takes place, which is again, to a great extent, filled up by the action of the sea and tides.

The lighthouse was built in 1849–50 under the direction of the late General Hartman Bache, of the United States Topographical Engineers. Being the first iron screw pile structure built in the United States, and having but few predecessors in the world, it excited much interest among its projectors, and every care was exercised to have both material and workmanship of the best quality.

The piles were driven about six feet into the sand, this being as far as the appliances then in use could accomplish.

In 1856 the horizontal braces at the Brandywine had become so bent and distorted by the action of the ice, that an additional row of piles was placed around the ice fender, those in place were lengthened out with cast iron sleeves, the whole continued up eleven feet above high tide, a system of diagonal rods introduced above the water and a platform built over the whole at the level of the first floor of the house.

About the time of the commencement of the construction of the iron pier in the Delaware Breakwater Harbor by the Government, the late Capt. M. R. Brown, Corps of Engineers, U. S. A., then in local charge of that work, was directed to make an examination of the Brandywine Lighthouse with a view to ascertaining the effect of sea water on the pile shafts.

This examination was made in July, 1873, after the iron had been subjected twenty-four years to the action of the water.

The plan then pursued was by the employment of a diver to remove from the shafts, as well as possible, the rust and adhering organic growths, and measure the diameters by means of calipers at certain vertical intervals above the bottom. As stated by Capt. Brown, "this was a work of greater magnitude than was anticipated," and in the light of a subsequent examination made by myself in 1880, more, however, with a view to ascertaining the general condition of the bottom than determining the effect of the sea water on the piles, was not calculated to give accurate results, both from the great difficulty of removing all the adhering material and the irregularity with which the corrosive action has taken place.

In his report on the subject, Capt. Brown gives a table of measurements and a diagram showing the variation of the diameters from 5 inches; the latter is reproduced here.

The piles marked *A* and *C* in the plan of the structure were originally 5 inches in diameter, and *B* and *D* and the numbered piles $5\frac{1}{2}$ inches, the former rolled iron and the latter hammered iron, all imported from England.

Many of the measurements of diameters taken in the examination of 1873 show an excess over the original dimensions; at these points it is fair to conclude that the adhering material was not thoroughly removed, or where the excess is but slight, the shaft may have originally exceeded its specified dimensions.

As this work was, however, of a new character at the time it was built, and inasmuch as numerous castings were prepared to fit accurately the pile shafts, it is not probable that any great variation from the established dimensions would have been admissible.

Some of the measurements, however, show a considerable decrease in diameter; for example, the pile marked "A" at points 4 and 6 feet from the bottom measures $4\frac{3}{4}$ inches, a decrease of $\frac{1}{4}$ of an inch in diameter; assuming this to be uniform around the pile, it would indicate a reduction of 1.9 square inches in area, or about 10 per cent.

In "No. 6," one foot from the bottom, the measurement was $4\frac{7}{8}$ inches, a decrease of $\frac{5}{8}$ of an inch, which, under the same supposition, would give a reduction of 5.1 square inches, or 21 per cent. in area, and 11.3 per cent. in diameter.

The same pile 6 feet above the bottom measures $4\frac{5}{8}$ inches, a reduction of $\frac{7}{8}$ of an inch, about 16 per cent., or supposing a uniform reduction around the pile, 6.96 square inches, or 29 per cent. in area.

These examples are selected as showing the greatest reductions of particular sections of the shafts as given by Capt. Brown, the least diameter of the section being taken as showing the possible loss. The diameters at right angles to the ones used above are in all but one case greater than those taken; but, as in the majority of the measurements, the adhering material evidently was not removed entirely, and as the method used in making the meas-

urements would give a diameter slightly greater than actually existed, it is probable that the reductions noted are not greatly in excess of those that have actually taken place.

It is noticeable that the greatest reduction has occurred on the hammered shafts, viz.: .875 of an inch in 25 years, or at the rate of .035 inches per annum. While the greatest in the rolled iron .25 of an inch in the same time, or .01 of an inch per annum.

And further, that the most serious corrosion is below the surface of low water beyond the action of the atmosphere, where, at certain points, there seems to be a concentration of the elements favorable to the most rapid deterioration, as is illustrated in the pile "C," where a hole 2 inches deep and 1 inch wide, and another 4 inches long and $1\frac{1}{2}$ inches wide and deep, occur. The destructive effect of this method of deterioration is shown in the existence of a crack extending 2 feet above the latter hole.

In 1879 one of the outer row of fender piles was broken off by the ice, and the manner of its breaking, viz.: at its connection with the system of horizontal braces near the plane of high water, led to the belief that the sand had washed away from the lower end and left it unsupported. During the following summer an examination was made to ascertain the cause, which was found to be as supposed.

During this examination, the necessary time to clean off and examine the pile-shafts could not be secured, but one of the braces of the original fender system that had been broken off was secured, and subsequently the broken pile.

Some of the piles standing were clear of adhering material for two feet above the sand, probably scoured by the shifting sand. Those so exposed to the view of the diver were reported as deeply seamed by corrosion.

The bar secured, however, was one of the original braces of the fender system $2\frac{1}{2}$ inches in diameter, and had been in the water thirty-one years. The diameter was increased from an inch to an inch and a half by adhering rust and organic growths, much of which was easily removed, and the iron found to be covered with a soft black rust easily washed off, leaving the iron bright in many places. But there was none of the ordinary reddish-brown rust commonly coating iron in the air. The

black coating, however, was rapidly converted into the brown rust on exposure to the air.

The piece was seamed in the direction of its length, with occasional holes to the depth of from an eighth to a quarter of an inch.

At one end of the brace was a portion of the cast iron socket originally supporting it, which had been broken off. This was found to be coated, after the removal of the adhering growths, to the depth of an eighth of an inch, with a soft, dark gray coating of metamorphosed iron, which could be removed readily with the finger-nail, but the piece retained the sharp outlines of its original form. The coating became hard after exposure to the air and did not separate from the iron, but the iron seemed rather to have become softened by the action of the water on its surface. After exposure the casting was covered with the ordinary brown rust.

No greater deterioration, where the wrought and cast iron were in contact, was observable.

The brace was sawed into a number of pieces, and on the interior was perfectly sound and bright.

The deepest seams resulting from the action of the water appear at the extremities of one diameter, while at the ends of the diameter at right angles to this the surface is but slightly roughened, and in cross-section the lines bounding the indentations are approximately parallel and not radial.

This probably arises from the position of the plates forming the pile from which the bar was rolled.

The effect upon the iron above the surface of the water exposed to the moist air and in times of rough weather thoroughly wet, has been different.

The ends of some of the pile shafts extending a few feet above high water and probably wet a part of nearly every day, although colored on the surface with rust, retain sharp edges of the top surface, show no disposition to seaming, and no appreciable diminution of diameter. This seems remarkable, although the pile is in an excellent position for examination, and a series of sharp blows with a hammer failed to detach any scale.

In the diagonal rods forming the bracing above the surface of the water, there is a marked alteration from the original section.

With the rust adhering, they present almost exactly the appearance of pieces of hemlock wood with the bark on, the thick scale of rust and paint being cracked by the swelling of the rust, so as to make the resemblance very striking.

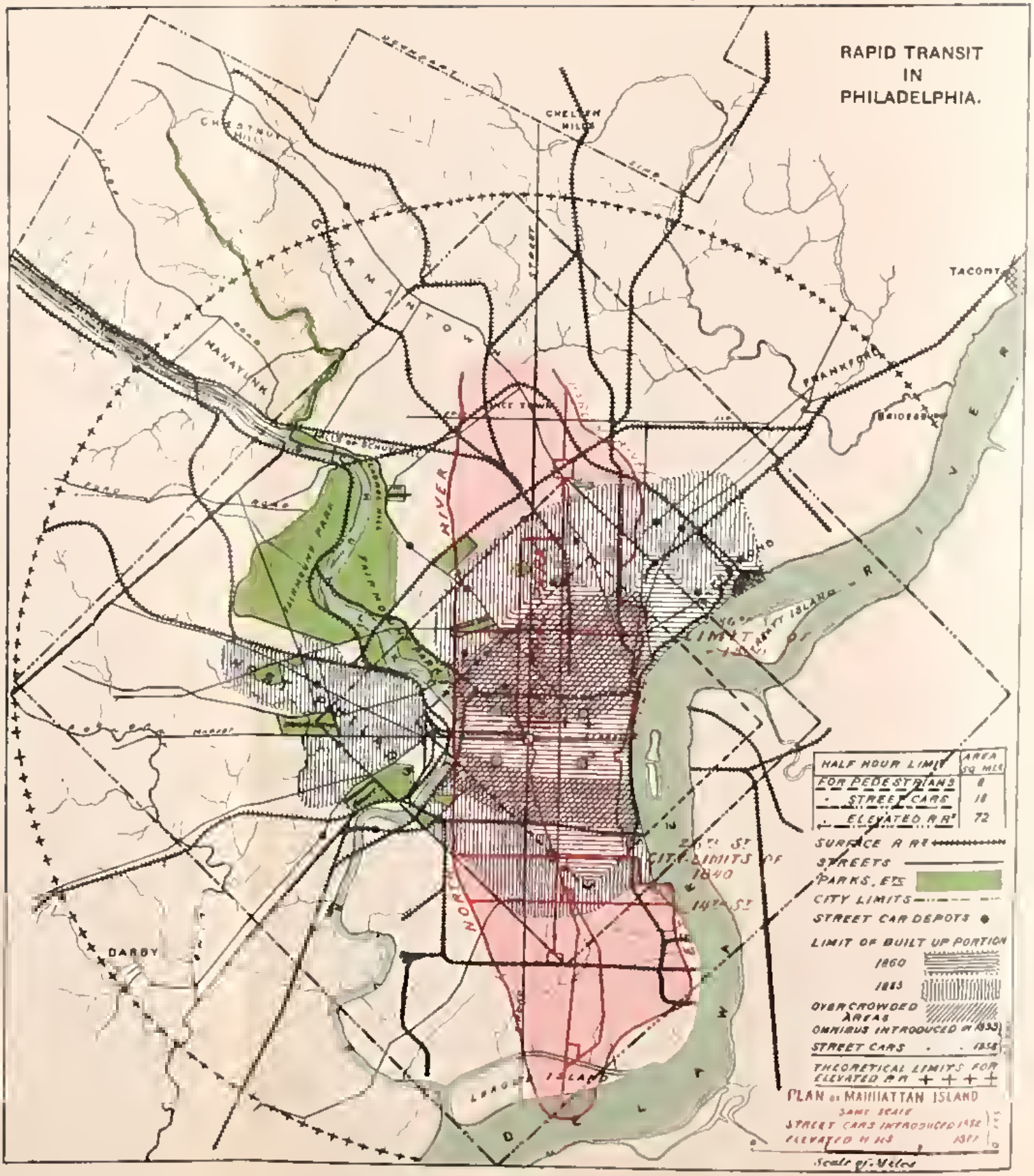
Upon the removal of the scale from these rods, the appearance was entirely different from that of the bar that had been continually submerged. There was no indication of the longitudinal seams, but a tendency to reduce the cross-section from a circle to an irregular polygon.

The effects noted above may be regarded as those which take place with a certain degree of uniformity throughout the entire structure. In addition to these, however, there are isolated points where there appears to be a concentration of the elements necessary to produce extensive deterioration, the amount of which it would be impossible to determine save by a detailed examination of each pile.

In Capt. Brown's report, pile No. 6 is stated to be "badly pitted or pock-marked." No. 7 "has grooves 5 inches long and deep enough to bury the thumb." Pile C "a hole 1 foot from the bottom about 2 inches deep and 1 inch diameter." Another "$3\frac{1}{2}$ feet from the bottom, 4 inches long, $1\frac{1}{2}$ inches deep and wide, from this a crack extends upward 2 feet, and is about 2 inches deep."

Such effects are doubtless occasioned by the presence of larger quantities of impurities concentrated at the points where they occur, and are those from which the most serious results must be anticipated.

It would appear, from the results of Capt. Brown's examination, which is confirmed by own observation, that the effect of the sea water on the Brandywine Lighthouse is more serious below the surface of the water, where there is a constant and uninterupted chemical action in progress, than takes place either between wind and water or in the air, although the total amount destroyed may be greater in the latter case than in the former.


RAPID TRANSIT
IN
PHILADELPHIA.
GERMANTOWN
MANAYUNK
CHELTEN HILLS
CHESTNUT HILLS
TACONY
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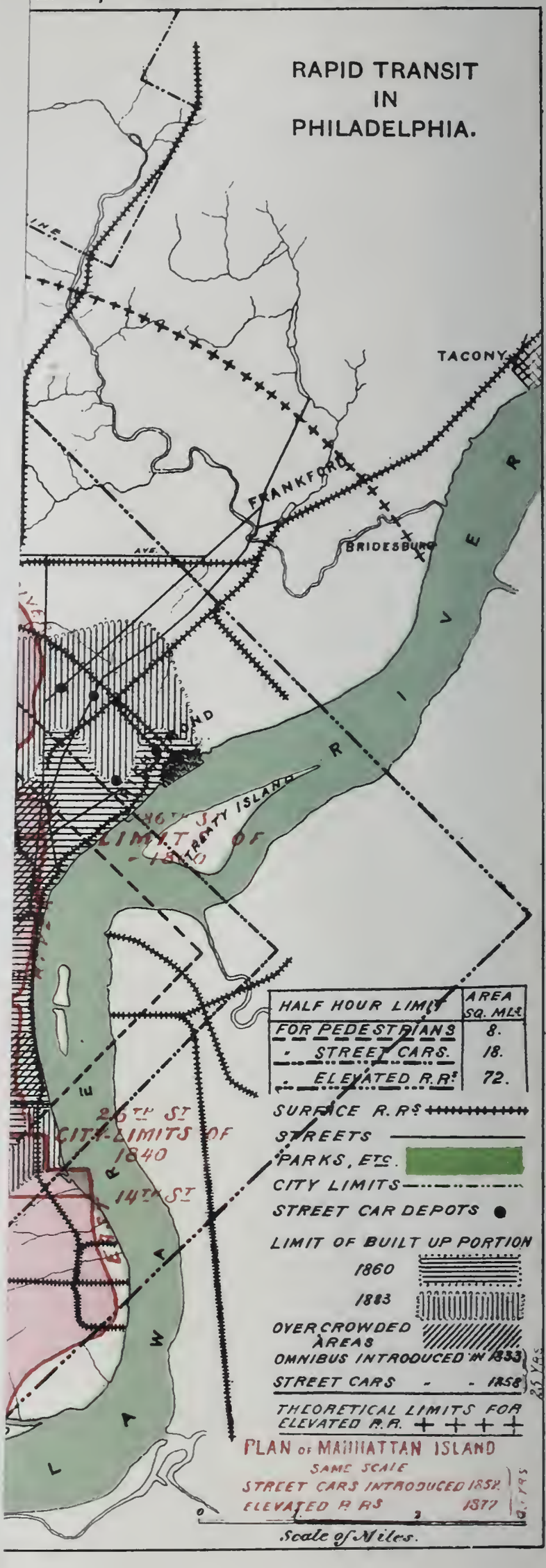
DELAWARE RIVER
SCHUYLKILL RIVER
NORTH
LIMIT OF BUILT UP PORTION
CITY LIMITS OF 1840
20TH ST
14TH ST
LIMIT OF BUILT UP PORTION
DARBY
LEAGUE ISLAND
HALF HOUR LIMIT
AREA SQ MILES
FOR PEDESTRIANS 8
STREET CARS 18
ELEVATED R.R.S 72
SURFACE R.R.S
STREETS
PARKS, ETC
CITY LIMITS
STREET CAR DEPOTS
LIMIT OF BUILT UP PORTION
1860
1883
OVERCROWDED AREAS
OMNIBUS INTRODUCED IN 1833
STREET CARS . . 1858
THEORETICAL LIMITS FOR ELEVATED R.R.
PLAN OF MANHATTAN ISLAND
SAME SCALE
STREET CARS INTRODUCED 1852
ELEVATED R.R.S 1877
Scale of Miles


RAPID TRANSIT
IN
PHILADELPHIA.
TACONY
FRANKFORD
BRIDESBURG
DELAWARE RIVER
SCHUYLKILL RIVER
LIMIT OF 1840
26TH ST
CITY LIMITS OF 1840
14TH ST
HALF HOUR LIMIT | AREA SQ. MLS
FOR PEDESTRIANS | 8.
STREET CARS. | 18.
ELEVATED R.RS | 72.
SURFACE R.RS
STREETS
PARKS, ETC.
CITY LIMITS
STREET CAR DEPOTS
LIMIT OF BUILT UP PORTION
1860
1883
OVERCROWDED AREAS
OMNIBUS INTRODUCED IN 1833
STREET CARS - - 1858
THEORETICAL LIMITS FOR ELEVATED R.R.
PLAN OF MANHATTAN ISLAND
SAME SCALE
STREET CARS INTRODUCED 1858
ELEVATED R.RS 1877
Scale of Miles.

XI.

RAPID TRANSIT.

By Prof. L. M. Haupt, Member of the Club.

Read May 17th, 1884.

An article appeared quite recently in one of our local papers containing this statement: "The enormous growth of travel on city railways in New York, especially since the construction of elevated railroads, is little short of marvellous." This was followed by a quotation of statistics from the letter of John I. Davenport, Esq., dated March 29th, 1884, addressed to Mr. Melville C. Smith, President of the Broadway Underground Railway. As this letter is deserving of more than ordinary consideration, I desire to call your attention to a few of its prominent features and to draw some additional conclusions therefrom, with special reference to our own city.

Topography.

It considers first the topography of New York City or Manhattan Island, which is about nine and a half miles in length from Castle Garden to the Sixth Avenue crossing of the Harlem River, and about two miles in average width. The area within these limits, as measured by the planimeter, being 18¾ sq. miles. The island is surrounded by navigable rivers, which, with its water connections, extending as far west as Minnesota, have given it great commercial supremacy. Originally the surface was rugged and rocky, with numerous swampy depressions, which it has been difficult and expensive to grade and drain.

As the opponents of Rapid Transit in Philadelphia have made the *topography* of the two cities the main point in the arguments *pro* and *con*, it may not be amiss to compare the conditions. Philadelphia, like New York, is situated between two navigable rivers, but which, for the built up portion, are a little farther apart than are those of that city. Instead of being an island it is a peninsula. West Philadelphia, in its topography, may be compared to Brook-

lyn; and Camden to Jersey City. Both cities adjoin a foreign State. If a plan of Manhattan Island be laid over one of Philadelphia, drawn on the same scale, so that the Battery coincides with League Island, and Sixth Avenue with Broad Street, the Harlem River at Sixth Avenue (150th Street) will be found above Erie Avenue, and the whole of this part of New York will lie between these north and south limits and the two rivers, with about an equal area to spare. Or, if the plan of New York be shifted so as to bring the City Hall up to Market Street, the Battery will be found at Washington Avenue, and Fourteenth Street at Girard Avenue, whilst the Harlem will just touch the county line road. If then, there is a necessity for Rapid Transit in New York, there is a greater necessity for it in Philadelphia, for *its need is proportional to the extent of surface and the distance of the residents from the business centers.*

New Yorkers have the additional great advantage that their lines of communication are nearly all direct, whilst Philadelphians, in crossing the city diagonally, must be continually turning aside to go around the corner.

Commercial Supremacy.

Mr. Henry C. Gardner, in an address to real estate owners in New York, in 1870, said: "Commercial prosperity is secured and retained only by constant enterprise. Seventy years ago (1800) Philadelphia was the first commercial city on this continent. She contained a population of 70,287,* while that of her greatest rival was only 60,529. But New York added to the advantages of her harbor those of the Erie Canal, and thus secured the Western trade and with it commercial supremacy. For years she experienced the flood tide of success; but in 1860 the ebb began, since which time her decline has been far more rapid than her advancement.

Population.

"Between 1800 and 1860 the increase of population in New York as compared with that of the United States was as 253 to 100, whilst from 1860 to 1870 the figures were reversed. In Brooklyn the population in 1860 was 266,661, and in 1870 it was

* This was within the old city limits.

396,661, showing a gain of 130,000, which was 17,328 more than that of New York for the same period. The ratio of increase being as 48.75 per cent. to 13.84 per cent. In 1840 there were only 14,342 persons living above Fourteenth Street, when the city limits extended only to Twenty-sixth Street. In 1860 the population above Fourteenth Street had increased to 313,494, whilst that of the Third Ward, which is west of the City Hall, had decreased from 11,581 to 3,757, a loss of 7,724 or about 70 per cent.

Between 1840 and 1860 the total population increased 500,959 or 160 per cent., yet the Second and Third Wards decreased 187 per cent. The part above Fourteenth Street increased in these twenty years over 658 per cent. against 160 per cent. for the entire city. Street railways were introduced in 1852, and in 1860 there were six lines in operation, carrying for that year 36½ millions of passengers.

During the next five years six more lines were added, and in 1865 these twelve lines carried over 82 millions of passengers, yet the movement was confined to the old limits at Eighty-sixth Street, and during the next five years no additional lines were built, although the patronage in 1870 exceeded 115 millions.

The ratio of increase of population for the sixty years prior to 1860 was 28 per cent. every five years, 5.6 per cent. a year, which, had it remained constant until 1870, would have given a population then of 1,334,973, an increase of 520,404, whereas the actual increase was only 112,672, showing a loss of 407,732, a population greater than that of the city of Brooklyn, all of which would have been located in the upper part of the city but for lack of transportation facilities. The mere pecuniary loss to the real estate interests from this cause is estimated at $500,000,000, the revenues from which, @ 2 per cent., would have been $10,000,000.

Time Limits of Travel in New York.

Thus it is seen that up to 1860 New York increased rapidly in wealth and population, when she outgrew her limits and overflowed into Brooklyn and New Jersey, the stages and street cars being incapable of making better time and thus extending their

distances. The limit of travel, as measured by time and convenience, in New York was then about four miles, and the business centre being at Wall Street, made it more expeditious and certain to reside even at some distance across the rivers than at the upper end of the island. Measured by time alone Harlem was 34 miles from the City Hall and Elizabeth, N. J., but 14. The convenience and certainty of travel by steam roads as contrasted with the sufferings and delays by the horse cars, in winter especially, placed an effectual barrier across the northward current and diverted it into the eastern and western channels.

Density and Distribution of Population.

"In 1860 the population of New York was 813,669, of which number 468,549 or 57.6 per cent. resided below Fourteenth Street, in a district covering but $3\frac{3}{4}$ sq. miles of the 38.11 included in city limits. In 1870 the population was 942,292, of whom 497,289 or 52.8 per cent., a little more than half, lived within the above limits; and in 1880, of 1,206,299 persons only 542,251 or 45 per cent., considerably less than half, remained in the aforesaid district. This diminution of 12.6 per cent. shows the combined relief afforded by the surface and elevated roads to this densely populated district, and is its own commentary on the inadequacy of the provision. New York waited too long for relief.

In December, 1864, a census of New York showed 495,592 persons in 111,000 families ($4\frac{1}{2}$ to a family) living in 15,309 tenements and cellars. An average of 32.37 persons or $7\frac{1}{4}$ families to a house. Again in 1869 there were 483,492 persons in 113,405 families occupying 14,872 tenements, an average of $31\frac{1}{2}$ persons to a house, and very nearly the same condition was found to exist in 1880, when there was an average of 31 to each tenement.

In Philadelphia, in 1870, there were 674,022 persons housed in 112,366 dwellings, giving 6 to each house. In 1860 the number was 6.3 to each house, and in 1880, 5.8. Here there are two extreme cases to which it may be said the same rule will not apply, but we will see on examination that it does, for "It's a poor rule that won't work both ways." New York is so densely inhabited not because it has no Rapid Transit facilities, but because they are wholly inadequate to provide for the wants of the community;

it needs more for the health and morality of its citizens, and Philadelphia with her 910,707* inhabitants, spread out over 129.3 square miles of area, needs them for concentration and economy of time and energy. It is a question of time *vs.* health, for if our facilities of transit do not keep pace with our increase of population we will soon be corralled by time limits, and the density, mortality and immorality of the population must increase correspondingly. In New York 75 per cent. of all the deaths occur in the tenement houses or hospitals, where in some wards, notably the Tenth, Eleventh, Thirteenth, Fourteenth and Seventeenth, the population ranges from 432, 353, 349, 314 to 309 to the acre, while the best authorities place the maximum density compatible with health at 100 to the acre.

In Philadelphia, in 1880, the Third Ward was peopled at the rate of 150 to the acre, and the Fourteenth was nearly as dense. The Fourth, Seventeenth, Twelfth, Thirteenth, Seventh and Tenth are all above the maximum limit (in the order given). These wards lie south of Pine Street and north of Vine, as stated in a previous paper on Intercommunications in Cities (Vol. II, 1881), where the subject of the distribution of the population is more fully treated, and some important deductions given, which need not now be repeated. It will be sufficient to indicate these overcrowded zones by a shade on the map, thus exhibiting their relative positions and extent, and showing where relief is desired.

Theoretical Consideration of the Relative Rates of Travel, Whether on Foot, by Street Cars, by Elevated or Underground Roads, or by Ordinary Surface Railroads, as Affecting the Areas Available for a Salubrious Distribution of Population.

As the velocities of travel are equal to the distances divided by the times, or $v = \frac{d}{t}$, let us assume a uniform value for t, variable values for v and determine the resulting values for d, and, as a fair basis of comparison, let us make *the time limit a half hour*, as being the average time which the business or laboring classes of a community require in going to, or in returning from, their

* Estimated for 1883.

occupations. The value of t will then be 30 minutes. In this time and at the ordinary velocities the distances traversed will be

	Miles.		Min.
For pedestrians,.....	2	or at the rate of one mile in	15
" horse cars, " cable system, ...	3	" " " "	10
" elevated, ...	6	" " " "	5
" underground or way trains, ...10		" " " "	3

It will probably meet the case fully to assume that each person traveling by any of the above means moves over the entire distance, that is, that a pedestrian makes a round trip of 4 miles from the perimeter to the business centre and back; hence the limits of a city where the residents go on foot would have a radius of *two miles* or an area of $12\frac{1}{2}$ square miles if people could move across it radially.

Under similar conditions the street car or cable city would be limited by a radius of *three miles* or an area of $28\frac{1}{4}$ sq. miles; the elevated railroad city of *six miles* with an area of 113.04 sq. miles, or *four times that of the street car*, and the underground railroad city a radius of *ten miles* or an area of 314 sq. miles. These theoretical limits, except the last, are shown on the map by the several circles described from Sixth and Market Streets as a business centre.

Practically, however, as there are no radial streets in the greater portion of these areas, and passengers are thus compelled to zigzag across the city diagonally, the areas will become squares with their diagonals on the principal axes, and the practical limits will be as follows:

Pedestrians,.....diag.	4	miles, area	8.00	sq. miles.
Horse or cable, ... "	6	" "	18.00	"
Elevated, ... "	12	" "	72.00	"
Underground,..... "	20	" "	200.00	"

whilst the total area of the city is 129.3 sq. miles.

With the business centre at Sixth and Market Streets however, the plan of *this* city does not admit of unlimited expansion in all directions, as the Delaware River will cut off the eastern angles of

the squares, thus reducing the practically available areas to about 6¾ sq. miles or 5 per cent. of the whole area for pedestrians;* 13½ sq. miles or 10½ per cent. for street cars, and 50 sq. miles or 44 per cent. of the entire area for elevated roads. The extent of these limits will be more clearly illustrated by reference to Plate I. From the above data it is evident that a rate of travel of 6 miles per hour is *altogether inadequate* to render available the territory of a city having an area of 129 sq. miles.

Verification.

To verify the above assumptions as to position and distances the present limit of the built up portion of the city has been indicated on the map, from information furnished by the Registry Department, and by comparing it with the square representing the street car city, it will be seen that the half hour limits of street car travel have already been reached and in some instances passed, and that the depots and stables are close to these limits, being generally inside.

Where there are diagonal avenues, as in the case of Ridge, Lancaster and Woodland Avenues, and the oblique streets in the northeastern section of the city, the improvements have slightly surpassed the limits, proving conclusively the effect of a reduction of time and distance in extending and rendering more valuable the taxable property of the city.

In the southern portion the buildings have not yet quite reached the street car limit, but as the residents are chiefly artisans and the manufacturing centre is north of Vine Street, this would bring them to the half hour limit from their center of occupations. But irrespective of these limits, as determined by linear distances from a centre, let us compare the *areas*. We have found the theoretical street car city to contain 13½ miles or 8,640 acres. The built up city as measured by a planimeter, excluding Fairmount Park, Woodland, Pennsylvania Hospital

* The actual area of the built-up part of the city at the date of the introduction of street cars 1858–59 was 7 square miles and the limits are found to concide very closely with the theoretical square above given, thus further corroborating the correctness of the assumed data. The centre of the built-up city is at Sixth and Cherry Streets and not at Sixth and Market Streets.

for Insane and the Almshouse grounds and Schuylkill River, contains about 16 square miles or 10,108 acres, leaving an excess over the street car city of 1,468 acres, located in the salients bordering the diagonal avenues previously mentioned. A part of this area is accommodated by the various railroads entering the city, but they cannot be regarded as fulfilling the requirements of rapid transit for a local or resident population, as the local trains are run at too long intervals, stations are too far apart and fares too high.

If it be true, as shown above, that *the city has surpassed her limits of travel by street cars*, then there should be a diminution in the percentage of increase in population and an overflowing in the direction of least resistance or to that portion most available and nearest in point of time. Let us see what the statistics have to say.

Census of Philadelphia City and County.

Year.	Population.	Increase.	Rate.
1800	81,009		
1810	111,210	30,201	37.3
1820	135,637	24,427	22.0
1830	188,797	53,160	39.2
1840	258,037	69,240	36.5
1850	408,762	150,725	58.5
1860	565,529	156,767	38.5
1870	674,022	108,493	19.3
1880	847,170	173,148	25.7

Here is a marked and rapid decline in the ratio of growth from 5.9 per cent. per annum in the decade ending 1850, to 2.5 per cent. in that ending 1880. Had the ratio of 1850 remained constant for these thirty years the population should have numbered 1,124,095, instead of 847,170, being a loss of 276,925 persons with all that it entails. Yet this additional population could not be housed in the present city without greatly endangering the health and welfare of the community and reducing it to the deplorable condition of the tenement districts of

New York, which are a disgrace to our civilization. Will any one say that this "City of Homes" has reached the limits of a ripe old age and must now decline in her senility for want of more rapid communications?

Again, if Philadelphia has reached the limit of growth by street cars, and there be an available spot for habitation outside of the city but within the time limit we have assumed, we must look there for an increase of population. To cross the Delaware River requires from five to eight minutes, and the boats run at intervals of seven minutes. Thus, in an extreme case, it may take fifteen minutes to cross the river; this is equivalent to one mile on foot, or one and a half in street cars, leaving a half mile more available for pedestrians and over a mile for those who ride to the ferry on the Camden side. We would then expect Camden to receive a large portion of the overflow. What are the facts?

The population from 1850 to 1880 is as follows:

Years.	Population.	Differences.	Per cent. increase in decade.
1850	9,479		
1860	14,358	4,879	51 per cent.
1870	20,045	5,689	40 "
1880	41,659	21,604	108 "

And it is believed that the ratio of increase since 1880 is even greater than 10.8 per cent. per annum.

Does Philadelphia desire to drive her population into an adjoining state?

In West Philadelphia the increase is as follows:

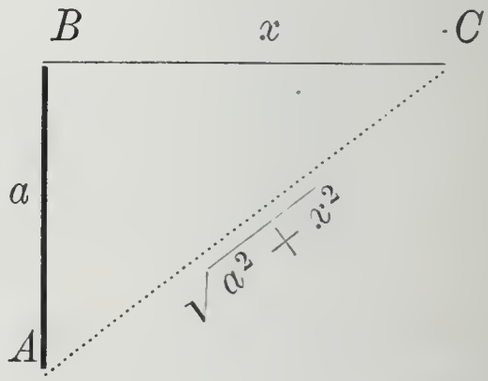
Year.	Population.	Increase.	Rate.	
1850	5,571	Before Consolidation of City in 1854.		
1860	23,738	18,167	326.	24th Ward.
1870	43,571	19,833	84.	24th and 27th Wards.
1880	69,341	25,770	59.	

The available space in West Philadelphia is the narrow strip between the Penna. R. R. and Woodland Avenue, hence the crowding out beyond time limits and the rapid decline in the ratio of growth.

Elevated Roads.

We have already shown that if the velocity of travel be increased to that of elevated roads, the area, within the half hour limit, would equal three times that of the present built up city, but since it is impossible to have such roads pass every door, we will confine our attention to two lines, running at right angles to each other through the same business centre, viz., Sixth and Market Streets. And here we are met by the query: Of what use would such lines be to the majority of citizens? The question resolves itself into this: How far from the "L" road may a person live so as to be able to save time by patronizing it rather than by walking in a straight line to his objective point, were that possible?

Let AB represent the line of railroad and C the residence of a citizen who must walk a distance x and ride a to reach A, or else, if possible, walk a distance $= \sqrt{a^2 + x^2}$. As the times of travel by the two routes must be equal for the outer limit and the velocities on x and a are unequal, we have the equation $\frac{x}{v} + \frac{a}{v'} = \frac{\sqrt{a^2 + x^2}}{v}$ in which v is the rate on foot and v' by the elevated road. This gives $x = \frac{a}{2r}(r^2 - 1)$, r being $= \frac{v'}{v} =$ ratio of velocities. If then $r = 3$ as it is in this case, x will be equal to $\frac{4a}{3}$; or $1\frac{1}{3}$ times the distance traveled on the railroad would be the distance one might walk to use it, if the time limit be made indefinite or unlimited. Thus the whole area of the city would be benefited by an L road and the sectors of tributary area would overlap. The central angle of this sector being 106° 16′, the four angles would



give 425°, or a total overlapping of 65°, which, in the absence of diagonals for walking, should more than equal the loss of time in making connections. For horse cars the locus of equal time intervals would be $\frac{5}{12}\ a$, or nearly half mile on foot to a mile by street car, and for way trains on railroads the distance is $\frac{1}{5}^2\ a$, or the reciprocal of that by horse car travel.

But as we have limited our distances to a half hour of travel, it is evident that this limit is reached at a point *on* the elevated road at six miles from the centre, and hence at that distance the citizen must live on the line of the road, while, if he walk at all, his distance from the line must not exceed that given by the formula $x = \frac{6 - a}{3}$ where a is the length of that portion of the elevated road used, measured from the center.

From this formula when a is zero, x will be two miles, and when x is zero a will be six miles. Straight lines joining these points will then give the perimeter of the half hour limit and will show the total available area tributary to the road within this time limit. This enclosed area is equal to 36 square miles for these two lines of railroad, but as the eastern salient will lie over the river it should be deducted, leaving about 30 square miles, or 19,200 acres as the tributary area,* and if the population be put at the healthful limit of 100 to the acre, the total population in this area would be 1,920,000, and if the annual patronage were only ten† times the total population, it would reach the large aggregate of 19,200,000 passengers for these two lines.

In New York the number of passengers carried on all lines in 1883 was 200 times the total population, that by the four elevated roads being 70 times, and so great is the need for more rapid transit that a bill authorizing the construction of the Broadway Underground Railway has passed the legislature, and the company is preparing to push the work vigorously. It is proposed to lay four tracks, two for through and two for way trains, the first to run from the Battery to 130th street in 17 minutes, or to High Bridge in 22 minutes and the north line of the city in 34,

* The present built up area is 16 square miles.

† In New York the average is 17½ times.

with but few stops, while the other would run more slowly and stop more frequently. The proposed capacity will be a million passengers a day, and it will carry freight at night.*

Boston, too, has just authorized the construction of a new form of elevated road for more rapid travel to Cambridge, and it is hoped that the request recently made of this city to grant the right to construct an "L" road in the northeastern section thereof, will receive prompt attention.

If the $2\frac{1}{2}$ per cent. increase of population in Philadelphia has remained constant during the past three years, the present population would be 910,707, whilst the estimated total street car travel is 110,644,571. Thus the ratio of travel to population is as 121 to 1. The travel here is divided between 17 lines, giving an average of about $6\frac{1}{2}$ millions to each line. In New York it is $7\frac{2}{3}$ millions.

As most of the opposition to the elevated roads is supposed to come from property owners along the routes, or from parties interested in surface roads, it may be reassuring to state that the effect of the improvements in New York has been generally greatly to enhance the values of properties on the line as places of business, and but temporarily to reduce the travel on the horse car lines, which in 1878, when the "L" roads began operations, were carrying about 161 millions, and in 1883 the same surface roads conveyed $176\frac{1}{2}$ millions, an increase of $15\frac{1}{2}$ millions. In addition to this the elevated roads have created a business in five years of over 92 millions of passengers, chiefly because of their increased facilities, and have kept people in New York who would otherwise have gone over the rivers. The *net* increase in valuation of real estate in New York for four years *prior* to the opening of the elevated roads, as given by the annual reports of the Tax Commissioner, was 21,363,680, while for the four subsequent years it was 134,348,616, an increase in four years of about 123 millions.

The elevated roads occupy an intermediate position in cost of construction, rate of travel and general utility between surface and underground structures, and there can be no doubt whatever that the time has fully arrived when this city, *for her own sake*,

* Since writing the above, we learn that the bill was vetoed by the Governor.

requires them, and should heartily cöoperate with any parties so proposing to improve and extend her resources.

It is not within the province of this paper to indicate either the location of or the form of "plant" best adapted to subserve these ends, but merely to urge the importance of providing the means to obtain them, and thus to promote the general welfare of the city and encourage its growth.

From these data and arguments we are led to the following conclusions:

1. The city has reached and already surpassed the ordinary limits of street car travel.

2. The ratio of increase of population is declining, chiefly from lack of more rapid and cheaper means of transit.

3. The present steam roads in the city cannot supply the demand as they are SURFACE lines; trains must move slowly and cannot be run at close intervals, fares are too high and stations too distant.

4. Camden, New Jersey, is rapidly gaining at the expense of Philadelphia.

5. The annual loss to the city in revenue from this cause will reach millions of dollars.

6. Unless relief is provided the density of the population must rapidly increase at the expense of health and morality.

7. Two lines of elevated railroads at right angles to one another and properly located, would benefit an area equal to double that of the built up portion of the city.

8. The fears of the opponents of elevated roads of losses to the city or the individual, from withdrawal of patronage or depreciation of property, are shown by experience in New York to be groundless.

9. If Philadelphia desires to retain even the present low rate of increase in population and high rate of salubrity, she must promptly respond favorably to the request of her citizens to be permitted to build elevated roads.

10. The limits of the city are not such as to warrant any corporation in building an *underground* road, were it allowed, with any fair prospect of returns for many years.

ADDENDA.

A local paper, issued May 21st, contained this statement: "There is an average of 843 people to an acre living in New York City."

This error was probably derived from a table published with the letter of Mr. Davenport, previously cited, where, under the head of "Population to the acre," occur the figures 841.16, but a closer inspection shows that they are on the horizontal line opposite the words: "Average to the block," and the block contains an average of 2.98 acres, which would make the population to the acre 282.3 instead of 843. This, moreover, is exclusive of the streets, parks, etc. The correct exhibit is given on page 6 of said letter, as follows:

"In the year 1880, including all the parks, streets and the comparatively uninhabited annexed district, the City of New York contained an average of 49.95 persons to the acre. * * Omitting that portion of Westchester County annexed to the city in 1874 and the Park, we find the average population to the acre on Manhattan Island in the year 1880 to have been 109.66 individuals" (to the acre). This is but an average of 9.66 above the health limit.

In Philadelphia between the Second and Seventh Wards on the south and the Eighteenth, Nineteenth and Twenty-ninth on the north, all included, the total population in 1880 was 490,443, and the total area between the rivers 5,829 acres, giving an average of 84.14 persons to the acre, which is 4.14 higher than the maximum limit as fixed by the best *English* authorities. Throughout this paper we have taken the French limit of 100 as our unit.

THE GROWTH OF CITIES, AS EXEMPLIFIED IN PHILADELPHIA.

By PROF. L. M. HAUPT, Member of the Club.

SUPPLEMENT TO THE ABOVE PAPER ON RAPID TRANSIT.

Read June 7th and 21st, 1884.

IT may safely be asserted that the material development of a city is a function of the number of its inhabitants, and this, in turn, is dependent on the political, social and physical conditions of the place.

Under the term *political* are included all those public and general conditions which tend to increase the safety and security of persons and properties; the *social* embrace the personal relations of one citizen to another in ordinary intercourse, business or pleasure, and the *physical* those external elements of creation or construction which sensibly and seriously affect the welfare of a community.

In so far as the instrumentality of man is concerned, it is possible greatly to modify one or all of these conditions, for good or evil.

It is my purpose in this paper to consider only that one of the numerous physical elements, which relates to the facilities offered by cities for the unrestrained exercise of the social element, whether it be in behalf of benevolence, business, pleasure, morality, or whatever object may incite one to a temporary change of place.

Society can only exist by association, and association is the fundamental principle and basis of the community. Hence, other things being equal, that city will be most prosperous and grow most rapidly where the facilities for such commingling are greatest. Thus it will appear that the problems of the best width and directions of the streets of a city, the relation of street to building areas, the means of locomotion to be employed in traversing the former, and their surface covering, are all of direct importance and interest to the inhabitants of a city.

Aside from the important relation which RAPID TRANSIT bears to the development of the locality, there are numerous others which must not be overlooked. Amongst them may be included the facility with which artisans may obtain remunerative employment, the rates of rents, cost of provisions and general supplies, the salubrity of the city as a residence, the stability of its government, the cleanliness of its streets, the proximity, in time and expense, of its business and residence districts, the quality, quantity and cost of its various supplies for domestic or manufacturing purposes—as water, light and heat—its sewage system, if it have any, etc. Many of these elements are interdependent, and in most of them the cost of transportation is an important factor, so that, in attempting to give you a resumé of the growth of Philadelphia, as a practical illustration of the relations between

cause and effect, I have naturally been forced into the history of her transportation facilities and their accessory works, including particularly her *ferries*, established in early colonial days (1682); *stage wagons* (1732) 50 years later; *Conestoga wagons* about 1758–60, a quarter century; *turnpikes* (1792–94), 34 years; *steamboats*, commenced prior to 1786, 28 years; *bridges* (permanent), 1800; *canals*, 1811–25; *tramways*, 1823–32; *railroads*, 1832; *omnibusses*, 1833, and *street cars*, 1858, with mention of notable buildings, epidemics and other items tending to affect the growth of the city.

The effect of these various movements can probably best be studied by arranging them in the form of a chronological table, as well as by a more systematic classification by subjects.

This exhibit will require too much time to discuss in all its details, but there are a few peculiar features which should be specially noted; for instance, it will be seen that, as a rule, every change attempted in methods of transportation provoked considerable opposition, resulting in some cases in riot and arson, but that as soon as the new line became an established fact, its success was immediate and other rival companies were at once organized; also that the growth in population fluctuates with the transportation facilities, the increment being rapid in smaller towns where distances are short, and increasing with the additional facilities for locomotion.

The introduction of omnibusses in 1833 was hailed as a boon, notwithstanding the racket and jar, because they reduced the time in transit and gave comparative rest. The substitution of street cars *a quarter century* later (1858) was a great relief and improvement in point of comfort, yet the saving in time was but slightly increased. During the interval from 1858 to this time (1884) the built up area of the city has increased from *seven* to about *sixteen* square miles, showing that the practical limits of street car travel have been surpassed, for if the rate of travel in a half hour for the pedestrian city be taken as two miles and that of street cars as three, we have $2^2 : 3^2 :: 7 : x$ and $x = 15\frac{3}{4}$ miles.

The interval between the introduction of street cars and elevated roads in New York was from 1852–77, or *a quarter century*, and as Philadelphia was six years behind her sister city in street cars, the quarter century, or time for her introduction of elevated roads, matured last year (1883).

An analysis of the travel by the street car lines shows, after the rapid increase of the first few years, an average increment on the north and south lines of a little more than 200,000 passengers; on the diagonal lines, of over 211,000; and of the east and west lines of only 171,000—the lines in the lower part of the city having the lowest increments.

The following description of the development of the various forms of transportation and their accessory works, compiled chiefly from Scharf & Westcott's "Philadelphia, 1609–1884," will be found both interesting and useful.

Ferries.

In early colonial days most of the transportation was effected by water, so that we find the ferries playing an important part in the growth of the settlement.

Scull & Heap's map of 1750 shows the following:

The lower ferry on the Schuylkill, 1696 (now known as Gray's).

The middle ferry, or Gardener's, at High Street, (now Market) Dec. 7th, 1682.

The upper ferry, or Scull's, at Fairmount (1692).

The ferry below the falls, Garrigues'.

The ferry just above the Wissahickon (often forded).

The ferry between Greenwich Point and Gloucester, on the Delaware (June, 1695).

Cooper's Ferry to Cooper's Point, N. J., chartered Aug. 18th, 1727.

Penrose Ferry (marked as a ford), 1750.

"Stage Wagons."

A line of stage wagons between Burlington and Amboy, N. J., was put in operation in 1732, and formed part of the line of travel from Philadelphia to New York, the rest of the distance being by water. This was probably the first public conveyance. The wagons made but one trip a week, and were without springs, which were not invented until 1787. In 1752 this line carried passengers twice a week, leaving Philadelphia by the "stage boat" on Tuesday, reaching Bordentown Wednesday, thence by "stage wagon with a good awning" to Perth Amboy on Thursday, and by a stage boat to New York on Friday.

Other lines between these termini were put on in 1753, 1757, the first through line, by land, time three days, 1759 (*via* Mt. Holly from Cooper's Ferry), and 1762. In 1766 the time of transit was reduced to two days by a stage wagon known as the Flying Machine. In 1771 this "wonderfully swift coach" was surpassed by a rival line, making the journey in a day and a half. In 1772 a third flying coach line (*via* Princeton) was inaugurated.

The line to Baltimore from Philadelphia went by way of boat to New Castle, thence to the head of Elk River, and thence *via* Chesapeake Bay to Baltimore; time about five days. In 1757 a line was opened to Annapolis *via* Reedy Island to Fredericktown, and thence by stage boat to the terminus.

In 1761 a stage ran from Philadelphia to Germantown three times a week.

In 1766 there was no regular line to the West.

The line to Lancaster was started in 1784 by Frederick Shaeffer who made the round trip in three days.

In 1786 a post line was opened to Pittsburgh.

In 1789 a two-horse coach was started by Mr. Martin Hausman, of Reading, to run weekly for the conveyance of passengers and letters between Philadelphia and Reading. It made its passage *through in two days.* Fare, $2.00. Letter carriage, 3d.

In 1796 four stages ran daily from Philadelphia to New York, one daily to Baltimore, and once or twice a week to Lancaster, Bethlehem, Wilmington, Dover, Harrisburg, Reading and Easton.

The stage to Easton was started in 1796, and made one trip a week.

Stages ran from Philadelphia to Long Branch in 1800.

The first line of coaches to Pittsburgh was started in August, 1804, making the trip one way in seven days. A daily line was put on in 1828. Fare, $18 to $22.

Stages continued to be the regular method of conveyance by land until the introduction of railroads, when the first cars were modelled from the Troy coach bodies, and were drawn by horses.

Up to about the end of the eighteenth century the roads were exceedingly primitive, and at times impassable. Stages were frequently laid up for weeks in consequence of mud. Roots, stones and ruts caused frequent, and sometimes fatal accidents.

Turnpikes.

The transition from pack horses to wagons was a gradual one, and met with the opposition invariably attending such improvements. The carriers regarded wagons and wagon roads an invasion of their rights and privileges, but were finally obliged to yield to the manifest advantages of the new method of transportation.

Conestoga wagons were first used, according to Rupp, in 1760. They were drawn by six, eight, or more horses, and moved in trains. This necessitated an improvement of the road surface, and led to the construction of numerous turnpikes. The first in the United States was that extending from Philadelphia to Lancaster, commenced in 1792 and completed in 1794 by a private company, at a cost of $465,000. This was followed by:

The Germantown and Perkiomen,	commenced	in	1801,
" Cheltenham and Willow Grove,	"	"	1803,
" Chestnut Hill and Spring House,	"	"	1804,
" Philadelphia, Bristol and Morrisville,	"	"	1804,
" " Brandywine and New London,	"	"	1810,
" Perkiomen and Reading,	"	"	1811,
" Ridge,	"	"	1812,
" Spring House and Bethlehem,	"	"	1814.

Roads.

Gray's Ferry road was authorized from Cedar street to Darby road in 1696. It was known as the King's great road.

Haverford road, from the upper (Powel's) ferry, was authorized in June, 1703. Numerous others were opened subsequently, but it seems unnecessary to refer to them specifically.

A traveler from New York to Philadelphia in 1825–6, says that, "when we left the steamboat 'Thistle,' at New Brunswick, eight stages were already waiting for us, having each four horses, and the passengers were so numerous that each stage carried from eight to nine persons. We continued our journey thirty miles by land to Trenton, on the Delaware. The road led through a hilly country, but carefully turnpiked, several pits being filled up to make the road even. This road is formed somewhat according to the manner of German turnpikes, of small beaten

stones, with side-roads and ditches. About four o'clock P.M. we arrived at Trenton, and immediately embarked in the steamboat 'Philadelphia.' Unfortunately we could not enjoy the handsome landscape, because as soon as we arrived on board we sat down to dinner, and afterwards it became dark."

Steamboats.

Jno. Fitch's small skiff, propelled by steam on Delaware River, July 20th, 1786, was not very successful.

August 22d, 1787, a successful trial was made with a boat forty-five feet long, propelled by paddles.

In 1788 a steamboat ran to Burlington at the rate of four miles per hour.

June 15th, 1790, a larger boat ran to Burlington at the rate of eight miles an hour, and it is estimated to have run nearly 3,000 miles during the season.

1797 a side-wheel boat was run on the Delaware from Bordentown to Philadelphia.

In 1804 Oliver Evans launched a stern-wheel boat running sixteen miles an hour.

The next improvement was the Phœnixville cross-head engine, built by Jno. C. Stephens in 1807. She began running on the Delaware to Bordentown in 1809, and continued until 1813.

This was followed by the "New Jersey" in 1812, and the "Eagle" in June, 1813.

In 1817 the steamboat "Ætna" (owned by Jos. Bonaparte) ran on the route from Philadelphia to Baltimore, making six miles an hour against the tide, thus establishing the success of steam navigation.

Omnibus Lines.

"As Philadelphia grew in population her citizens demanded quick, regular and cheap conveyance from the business centres to the outskirts of the city."

The Chestnut Street hourly stage coach, know as the "Boxall," after its proprietor, was started December 7th, 1831, but had a short life.

"The first omnibus line in this city was established in 1833,

and ran every hour between the Navy Yard and Kensington, via Second Street to Deschamp's Hotel on Beach Street, near Shackamaxon; fare twelve and a half cents. The line increased rapidly, and became an extensive establishment with many coaches, which not only ran upon Second Street, but upon other routes."

The next line ran from the Merchants' Coffee House, on Second Street, out Chestnut to Beach, near the Schuylkill, and down the latter to Walnut and return. In July the coaches ran every quarter of an hour. "The success of these lines was immediate, and citizens generally clamored for like accommodations on other routes." In August a third line was added from the Coffee House to the depot of the Columbia Railroad, at Broad and Vine Streets. Other lines were soon started; one of these ran from the Coffee House up Second to Arch, to Sixth, to Buttonwood, to John (now Marshall), to Spring Garden (not then opened), and to the Germantown depot at Ninth and Green. The principal streets were soon occupied. The fares came down from twelve to ten cents, to six, five, and even three cents where the competition was strong.

"Until 1858, the year of street cars, or for a quarter of a century, these vehicles were the only convenient and accessible means of local travel."—*Scharf & Westcott.*

According to *Watson's Annals*, omnibusses began running at half-hour intervals between the Coffee House and Fairmount on June 1st, 1833.

Lippincott's Gazetteer, for 1855, says: "There are 47 lines of omnibusses, running 428 coaches. Ferry-boats run every five minutes to Camden, every half hour to Gloucester and Red Bank, every hour to Bridesburg and Tacony, and several times a day to Wilmington, Burlington, Bristol and Bordentown, while daily or tri-weekly lines run to various points on the river and bay."

In New York, at the same time, there were 682 omnibusses drawn by 4,546 horses, and of city railroad lines five, employing 178 cars and 1,967 horses.

Canals.

In 1762, David Rittenhouse and Dr. Wm. Smith, Provost of the University of Pennsylvania, surveyed a canal route to con-

nect the Susquehanna and Schuylkill Rivers by way of the Swatara and Tulpehocken Creeks. The Union Canal, since built, passed over part of this route. In 1764 they also induced the American Philosophical Society to order a survey for a canal between the Chesapeake and Delaware Bays. The geographies of 1763, say "there is an easy communication with Maryland which comes within four miles of the Chesapeake Bay," and "that a project was once set on foot for joining the river and bay by an artificial canal, but it met with such opposition from the inhabitants of Virginia and Maryland that it come to nothing."

On September 29th, 1791, a company was incorporated to begin the canal to connect Lake Erie with the Ohio River, but it failed from lack of timely aid from the State.

The Union Canal was incorporated in 1811, and the first boat, "the Susquehanna," passed the summit level December 30th, 1827.

The Schuylkill Navigation Canal was completed in the year 1825.

The Delaware and Schuylkill Canal Navigation Co. was incorporated April 10th, 1792.

Railroads.

The first railroad set up in America was the experimental one built by Thos. Leiper in the yard of the Bull's Head Tavern, on Third Street above Callowhill, in this city, in 1809. It was laid of two parallel oak stringers about four feet apart, supported on sleepers about eight feet distant. The grade was $1\frac{1}{2}$ inches to the yard $= \frac{1}{24}$. Length 64 feet. One horse drew on this track a load of 10,696 pounds. Immediately afterwards the railroad from Leiper's quarry on Crum Creek to the landing at Ridley, Delaware County, three-quarters of a mile, was built. It was the first practical railroad in the United States, and was in use until superseded by a canal in 1828.

Philadelphia and Columbia (Pennsylvania Railroad).

On 31st of March, 1823, an act was passed incorporating "The President, Directors and Company of the Pennsylvania Railroad Co.," with authority to lay out a railroad from Philadelphia to Columbia. After much contention over the location in Phila-

delphia, it was "provided that before the contract was made for any part of the said railroad between the western shore of the River Schuylkill and the intersection of Broad and Vine Streets, the city shall construct a railroad down Broad to Cedar Street with authority to construct a branch or branches from any point of the Pennsylvania Railroad east of the Schuylkill, not farther north than Francis Street (now Fairmount Avenue), and carry the same to any point or points on the River Schuylkill or Delaware within the limits of the city."

The Broad Street Road from Vine to Cedar was authorized by ordinance in January, 1833, and was finished and opened December 9th, 1833, in connection with the *Northern Liberties and Penn Township Railroad.* The cars were run on Broad Street to the intersection and out to the Columbia Railroad Bridge. As this road was so far from the business part of the city that the cost of drayage was one-third the freight from the City to Boston or Charleston by water, or to Lancaster by land, the Board of Trade memorialized the City Councils in January, 1835, to establish a system of tramways to bring freight "to the vicinity of the business part of the city." For the line of this road they suggested that it should commence on the Delaware at the Drawbridge and pass up Dock Street to Third, thence to High, up High to Broad Street Railroad, and continue out High Street to Ashton Street on the Schuylkill front. This involved the removal of the market houses and led to a bitter contest. It was also opposed by the merchants who had built on Broad Street. It was authorized in November, 1835.

In April, 1832, the proprietors of the Lancaster and Pittsburgh stages placed a car on the Columbia Railroad to run from the inclined plane westward to end of track. It was drawn by horses.

By the middle of September, 1832, the cars were run from Broad and Callowhill Streets to Paoli, Chester County, the passengers crossing the Schuylkill in boats. The first trial of a locomotive was made between Broad Street and the Schuylkill at the end of September, 1832.

On December 25th (Christmas Day) of the year 1833, the Philadelphia and Columbia Railroad was opened as far as West Chester and to Columbia, 181.6 miles, in April, 1834. The open-

ing excursion ran from Lancaster to the West Chester depot on Broad Street in 8½ hours, including stoppages. The cars were operated by the stage owners. Its route was from Eighth and Market Streets to Broad, thence to Willow (now Pennsylvania Avenue), thence to Fairmount and along the east bank of the Schuylkill to the Columbia Railroad Bridge (now used by the Philadelphia and Reading Railroad), and thence *via* the inclined plane to Belmont, and so on to its terminus.—*Watson's Annals.**

Mitchell's Compendium of Internal Improvements (84 pages), published in Philadelphia, in 1835, and the precursor of *Poor's R. R. Manual*, says: "The Philadelphia and Columbia Railroad leaves the depot at the intersection of Vine and Broad Streets, Philadelphia, passes up the Schuylkill to the viaduct, a distance of three miles, etc, etc. Cost, $3,595,809.98. Length, 81.6 miles.†

A branch of the above Railroad extends eastward, through Spring Garden and the Northern Liberties, to the Delaware River; length, 1.3 miles.

And another branch extends southwardly, down Broad Street, through the districts of Moyamensing and Southwark, to the Delaware River, near the Navy Yard; length, 2.8 miles.

The Peoples' Line to Pittsburgh started from Third Street Hall, corner of Willow, and in November, 1834, advertised that they ran through in 56 hours. In the Summer of 1835, cars and boats ran through to Pittsburgh, partly by canal and portage railroad, in 3½ days.

Two pleasure cars were put on the eastern division of the road in May, 1832, and ran from Callowhill street to Lemon Hill, hourly every day, for 25 cents.

PHILADELPHIA, GERMANTOWN & NORRISTOWN RAILROAD.

The Philadelphia, Germantown & Norristown Railroad was chartered February 17th, 1831, and opened June 6th, 1832. Cars

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* W. H. Wilson, in his *Notes on Internal Improvements of Pennsylvania*, gives the location of the depot as Broad and Vine Streets, then the northern limits of the city. The road was intended to be operated by horse power, and was so used for several years. Steam was applied about the close of 1834, when two locomotives were running. The next year there were seventeen.

† Average per mile, $44,067.

carried 35 passengers. On November 23d, 1832, a locomotive was put on the road, and the following advertisement appeared November 26th, 1832: "The locomotive engine built by M. W. Baldwin, will run when the weather is fair. On rainy days horses will be used."

This was the first railroad operated by steam in Philadelphia. On the trial trip the cars ran through in 45 minutes, and each car had but one horse. There were six round trips a day, leaving Philadelphia at 7, 9, 11 A.M., and 2, 4, 6 P.M. Fare each way, 25 cents.

The Norristown Branch was opened to Manayunk October 18th, 1834, and to Norristown August 15th, 1835. The depot was at Ninth and Green Streets.

THE WEST CHESTER RAILROAD

Was incorporated February 18th, 1831, and by the middle of August, 1832, a car could be driven from West Chester to the junction with the Pennsylvania Railroad. There was but a single track, with turnouts every mile. This part of the road was opened September 13th, 1832. The road was not finished to Philadelphia for some time afterward. In 1834 the Company bought a lot on the east side of Broad Street below Race (where the City Armory now stands), for a combined depot and hotel. The rear of the lot was used as a shelter for the cars, which began running through on Christmas Day, 1833.

THE DELAWARE & SCHUYLKILL RAILROAD

Was incorporated April 23d, 1829, under the title of the Northern Liberties & Penn Township Railroad Co., to construct a road over any expedient route from Front Street at or near Willow, in the Northern Liberties, and running on or near Willow Street westwardly, and thence by such route as the Commissioners of Spring Garden might permit, and until the Columbia Road was intersected, with permission to carry the road to the Schuylkill River north of Vine Street. This road was finished and opened from Broad Street to the Delaware in April, 1834, and on the 23d of that month public notice was given that pleasure cars would run at stated periods from Third Street Hall

to the Schuylkill Bridge and Peter's Island. They were drawn by horses. The depot at the Willow Street wharf was completed about January, 1835.

THE WEST CHESTER & PHILADELPHIA & BALTIMORE CENTRAL RAILROAD,

A rival line, incorporated April 11th, 1848—but not chartered until 1850. It was ultimately built to connect with the Baltimore Central, chartered March 17th, 1853. The depot was at the northeast corner of Eighteenth and Market Streets, but subsequently removed to Thirty-first and Chestnut.

SOUTHWARK & PHILADELPHIA, WILMINGTON & BALTIMORE RAILROAD.

This was originally known as the Philadelphia & Delaware County Railroad. It was authorized April 2d, 1831.

The same act also gave authority to lay tracks in the district of Southwark from the Delaware River to Broad and Cedar Streets, and to connect with the Delaware County Railroad. The route adopted was from South and Swanson, down the latter to Prime (Washington Avenue), thence to Broad, and up Broad to South, connecting with the City Railroad on Broad Street.

On November 29th, 1834, five or six cars were put on and ran out the Columbia Railroad to Peter's Island.

In 1836 a supplementary act was passed changing the name to the Philadelphia, Wilmington & Baltimore, and conferring other privileges.

The portion from Wilmington to the Susquehanna River was opened for travel May 5th, 1837.

In 1842 the depot was established at southeast corner Eleventh and Market Streets. Cars were drawn out by horses to Broad and Prime, where the locomotives were attached. The station at Broad and Washington Avenue was finished in May, 1852, at a cost of $100,000. It was the finest in Philadelphia.

The Eleventh Street station was then occupied by the Pennsylvania Railroad Co., which company, on July 2d, 1881, bought the entire line of the P. W. & B. for $16,675,692.

CAMDEN & AMBOY RAILROAD.

The first report was made in June, 1831. Surveys were begun June, 1830. The road was finished with single tracks between Bordentown and Amboy by the middle of January, 1833, and on the 22d of that month the steamboat "Trenton" began running. The United States mail was sent *via* Camden, December 29th, 1834, and the road fully opened in the Spring. In July, 1833, a locomotive ran at the rate of 13 miles in 31 minutes, and the next year it was regarded as an extraordinary evidence of rapid traveling that the entire trip of 94 miles could be made in 4¾ hours. The depot was at Walnut and Delaware Avenue, whence a ferry-boat left for Camden.

THE PHILADELPHIA & TRENTON RAILROAD

was incorporated February 23d, 1832, to lay tracks from Kensington through Frankford and Bristol to the Trenton Bridge. It was completed November 1st, 1834, and a locomotive put on which ran 28 miles in 1½ hours. The depot was between Front Street and Frankford Road, north of Harrison Street. March 27th, 1834, the company was authorized to connect with the Northern Liberties and Penn Township Railroad, and to extend its tracks to Third and Willow, where the building known as the Third Street Hall was used by that company as depot and hotel. In February, 1835, the company was empowered to bridge the Delaware and extend its tracks to Jersey City. The extension on Front Street, through the thickly built up section of the city, of a steam road laid on the surface of the streets, was so bitterly opposed that on July 27th, 1840, a mob collected, and after a severe struggle with policemen and workmen, tore up a portion of the track and set fire to the hotel occupied by the President of the company. The attempt to construct the road was abandoned for many years. Passengers took boat for Tacony and there connected with the cars.

PHILADELPHIA & READING RAILROAD.

The Philadelphia & Reading Railroad was chartered April 4th, 1833. Work was begun September, 1835, and portions of

the road were opened in July, 1838, and to the coal fields in 1841. Richmond Branch from Falls to Delaware, 5 miles, was completed in 1842. Road opened from Pottsville to Peters' Island January 1st, 1842. In 1850 the company bought the improvements belonging to the Philadelphia & Columbia Railroad from Broad and Vine to and including the inclined plane, which was abandoned.

This company has leased the Schuylkill Navigation from January 1st, 1870; Susquehanna Canal from January 1st, 1872; North Pennsylvania & Delaware & Bound Brook, May, 1879; Central Railroad of New Jersey, etc.

NORTH PENNSYLVANIA RAILROAD.

Chartered April 8th, 1852. It was finished to Gwynedd early in 1855, and formally opened as far as Fort Washington on July 2d, 1855, and to Bethlehem in 1857. The station was at Front and Willow until 1864, when it was moved to Germantown Ave. and Thompson Street, and soon after to Berks and American.

LEHIGH VALLEY RAILROAD.

Was incorporated under the name of the Delaware, Lehigh, Schuylkill and Susquehanna Railroad Company, April 21st, 1846. Surveys not commenced till 1850. Work commenced in Spring of 1851, and was finished September 24th, 1855.

PENNSYLVANIA RAILROAD.

Incorporated April 13th, 1846. Charter was granted February 25th, 1847. Work west of Harrisburg was begun July 16th, 1847. 61 miles were opened to Lewistown September 17th, 1849. Connection was made with the old portage road over the Alleghenies in 1850, and on the 10th of December, 1852, the cars were run through from Philadelphia to Pittsburgh. On February 15th, 1854, the route over the mountain *via* Cresson was opened and the portage planes abandoned. In 1853 the lot at Thirteenth and Market, now known as the Grand Depot, and covered by Mr. Wanamaker's stores, was purchased and used for freight purposes. Another freight station was also built a few years later at Sixteenth and Market Streets, and a third at Dock and Delaware Avenue.

In 1854 the passenger depot was at Eleventh and Market

Streets. In 1864 it was removed to the site at Thirteenth and Market, again to Thirty-Second and Market, and finally to Broad and Filbert, February 16th, 1881.

Bridges.

The first bridge across the Schuylkill was constructed as a military necessity. General Israel Putnam built a bridge of the floating stages used by ship carpenters at the Middle Ferry in the winter of 1776–77. It was a great convenience, but was removed on the evacuation of the city in September, 1779. The British built another floating bridge at Gray's Ferry, which was finished October 20th, 1777, and two days later was moved up to Middle Ferry. It was destroyed by a storm on October 28th, but rebuilt in two weeks. After the British fled it was removed to Gray's Ferry, and the old bridge at Middle Ferry was restored. This latter was carried away by a freshet in the spring of 1780. It was again replaced and rented for £8,400, but was swept away by ice and high water March 15th, 1784, and rebuilt in 1786.

It was then that Thomas Paine proposed an iron segmental arch of 20 feet rise and 300 or 400 feet span, to be erected over the river at High Street. A company was chartered with a nominal capital of $66,666.66. Designs were invited, but before any progress was made all the floating bridges were again swept away by the flood of 1789.

Then Councils determined to build a "permanent" bridge, but lacking funds applied to the State for aid. It was not until March 16th, 1798, that an act was passed organizing the company with a capital of $150,000 to build the bridge within five years. The ferry rights were sold to this company for $40,000.

Timothy Palmer's design for a wooden structure was approved, and the corner-stone laid October 18th, 1800.

"The constructing engineer encountered many obstacles, some of which were caused by the malice of the opponents of the bridge, but he conquered them, and on January 1st, 1805, it was thrown open to travel. The roadway was in the centre, with footwalk on the outside. Cost, nearly $300,000. On March 16th, 1839, a bill was passed by the Legislature authorizing the construction of free bridges over the Schuylkill at Philadelphia. This led to the sale of the bridge to the City in 1840 for $80,000, when it was made

"free." In 1849 it was remodelled to carry the Pennsylvania Railroad Company's tracks, and remained in use until November 20th, 1875, when it was destroyed by fire. The Pennsylvania Railroad Company built a Howe truss on the old piers in 207 working hours during December, 1875, which is still standing but in bad order, although it has been frequently repaired. The bridge was only intended to last five years.

GRAY'S FERRY BRIDGE.

In 1806 an attempt was made to incorporate a company to build a bridge at the lower ferry, but the scheme was strongly antagonized, and, as the contestants could arrive at no compromise, the floating bridge (ferry) remained until 1838, when the Philadelphia, Wilmington and Baltimore Railroad Company built its bridge, which, with the ferry rights, cost nearly $200,000. It was made free in 1839.

FAIRMOUNT BRIDGE.

A floating bridge was built soon after the close of the Revolution. It was destroyed by a flood in January, 1789, and again in 1810, when a company was chartered to build a permanent bridge (capital, $40,000), and construct a road from the Lancaster Turnpike to Ridge Avenue at Ninth Street. The single span of 340 feet, built by Wernwag, was the result. The corner-stone was laid on April 28th, 1812, and the bridge stood until September 1st, 1838, when it was destroyed by an incendiary. It was succeeded by the "Wire Bridge," of Chas. Ellett, Jr., opened January 2d, 1842, which did service for upwards of thirty years. In 1874 the Keystone Bridge Company erected the present structure, which has a length of 1295 feet from shore to shore, and 1430 feet more for abutments and approaches.

FALLS BRIDGES.

Kennedy & Carpenter built a chain bridge at the Falls of Schuylkill in 1809, which broke down in 1811. It was replaced by another bridge by authority of an act passed April 2d, 1811, and, when this latter gave way in 1816, White & Hazard constructed a wire suspension bridge from the top windows of their mill to some large trees on the west side, from which there was a descent by steps. Only eight persons were allowed on the bridge

at one time. It cost $125 and was the first wire bridge in the United States, and probably in the world.

"About the end of 1817 the Schuylkill Falls Bridge Company completed the wooden bridge that was destroyed by the flood of February 21st, 1822.

"In 1829 another company, under the same name, erected a new bridge that stood until burned on August 26th, 1842, and was succeeded by the 'Old Red Bridge,' which was swept away by the freshet of October 23d, 1878."

The second permanent bridge in Philadelphia County was the one built over the Schuylkill, opposite "Flat Rock," in 1810. It was broken down September 19th, 1833, by two teams drawing heavy blocks of marble passing at the same time. The damage was soon repaired, but on September 2d, 1850, the Conshohocken bridge was washed down against it and carried it off. This bridge was opposite the end of Domino Lane, Manayunk.

SCHUYLKILL NAVIGATION "TOW" BRIDGE.

This bridge is situated at the foot of canal navigation on the east side of the river. It is built at a slight angle, so that its eastern landing is not far below the Manayunk bridge.

MANAYUNK BRIDGE.

On the 24th of March, 1832, a company was incorporated to erect a bridge over the Schuylkill River and Canal at the town of Manayunk. This bridge was finished in 1833 and occupied the site of Righter's Ferry, which is supposed to have originated as early as 1707 or 1708.

COLUMBIA BRIDGE.

The Philadelphia and Columbia Railroad crossed the Schuylkill just below Judge Peter's residence (now Belmont). The bridge, which is now in use by the Philadelphia and Reading Railroad, was opened in March, 1834. It has escaped all accidents by fire or flood.

READING RAILROAD BRIDGE AT FALLS.

The Philadelphia and Reading Railroad Company also built a wooden bridge at the Falls, which was opened January 10th, 1842, and destroyed by fire on the 26th of August following. In

1843 a stone bridge was begun. The present askew arch was built in 1853–56.

GIRARD AVENUE BRIDGE.

This bridge was authorized by act of March 27th, 1852, at a cost of $175,000. It was finished in the summer of 1855, but was so poorly constructed that in December, 1872, the Grand Jury made a presentment of its dangerous condition, which not being respected by Councils, a true bill was taken out against them for maintaining a nuisance. A temporary structure was then put up and used during the erection of the present magnificent bridge, which cost $1,404,445. It is 1000 feet long and 100 wide, being the widest in the world. It was opened July 4th, 1874.

CHESTNUT STREET BRIDGE.

Authorized by act of 1852 to cost $175,000. It was not begun until 1857. The Chestnut and Walnut Street Passenger Railway Company was required by charter to contribute $100,000. The bridge was constructed by our late, lamented president—Strickland Kneass, and opened June 23d, 1866. It is 1528 feet long.

PENNSYLVANIA RAILROAD BRIDGE AT FILBERT STREET.

This is an iron deck bridge of three spans, built by the corporation for its own use. It was finished February 16th, 1881, and forms part of the elevated line to Broad Street Station.

SOUTH STREET BRIDGE.

This structure, it is said, was not a necessity, but was forced upon the people of the city by the Legislature, which passed an act on April 1st, 1861, requiring Councils to construct a bridge at a cost of not over $250,000. The bill was disapproved, but passed over the veto (May 14th). Councils refused to obey the legislative mandate for five years, and on April 5th, 1866, a supplementary bill was passed, appointing commissioners to build the bridge for a sum not to exceed $600,000, subsequently increased to $800,000. On March 30th, 1870, a contract was made with John W. Murphy, and the bridge was opened for pedestrians November 30th, 1875, and for general travel February 17th, 1876. It is 2419 feet long, including approaches. In less than two years the masonry approach on the west side fell from defective foundations.

PENNSYLVANIA RAILROAD AT ARSENAL.

This bridge, with a draw in the middle, was designed by Mr. J. H. Linville, and built in 1862. It is believed to have been the first bridge erected in the United States with wrought iron posts.

PENROSE FERRY BRIDGE.

This ferry was a consequence of the establishment of the pest-house on Fisher's Island. In 1776 Samuel Penrose was named as the ferryman. In an act of the Legislature, passed March 31st, 1806, this was called the lower ferry, and Gray's Ferry, the upper bridge. An act was passed April 9th, 1853, incorporating the Penrose Ferry Bridge Company. They put up a bridge, which was found to be weak and dangerous, so that a new one was thrown open to the public on June 30th, 1860, but it was not made free until some years later. On July 7th, 1876, the center span fell into the river, and another bridge was completed January 25th, 1878.

Street Car Lines.

Fares on all lines, originally five cents, were raised to seven, and subsequently reduced to six and in some cases five; exchanges, seven cents, now nine.

	Chartered.	Opened.
Fifth and Sixth Sts. (Frankford and Southwark),	March 12, 1856.	January 21, 1858.
Philadelphia and Darby (Woodland Avenue),	April 28, 1857.	
West Philadelphia (Market St.),	May 14, 1857.	July, 1858.
Tenth and Eleventh (Citizens'),	March 25, 1858.	July 29, 1858.
Race and Vine (Hestonville, M. and F.),	April 13, 1858.	September 8, 1858.
Arch Street Branch " " "	April 16, 1858.	1859.
Spruce and Pine,	April 9, 1858.	December 4, 1858.
Second and Third,	April 10, 1858.	
Germantown,	April 21, 1858.	Summer, 1859.
Green and Coates,	April, 1858.	1859.
Chestnut and Walnut (Philadelphia),	March 26, 1859.	Summer, 1859.
Fairmount P. Ry. Co. (Hestonville, M. and F.),	April 6, 1859.	
Thirteenth and Fifteenth,	April 8, 1859.	1859.
Seventeenth and Nineteenth,	April 12, 1859.	1859.
Ridge Avenue and Manayunk Branch,	March 28, 1859.	1859.
Girard College (Ridge Avenue),	April 15, 1859.	1859.
Richmond and Schuylkill (Girard Avenue),	March 26, 1859.	
Lombard and South,	May 16, 1861.	
Navy Yard, Broad St. and Fairmount,	May 16, 1861.	(Unconstitutional.)
Frankford and Holmesburg,	July 8, 1863.	
Seventh and Ninth (Union),	April 8, 1864.	
Wissahickon, Roxborough and Plymouth,	April 8, 1866.	
Schuylkill River (22d and 23d St.), (Phila. and Gray's Ferry),	April 16, 1866.	
Empire (12th and 16th St.),	February 10, 1869.	
People's (Callowhill St.),	April 15, 1873.	
West End (in West Philadelphia),	April 15, 1873.	
Continental (18th and 20th St.),	September 8, 1873.	

CHRONOLOGICAL TABLE OF POPULATION,

TRANSPORTATION FACILITIES AND SOME OF THE PRINCIPAL EVENTS AFFECTING THE GROWTH OF PHILADELPHIA.

Year.	*Number of Houses.*	*Population City and County.*	*Increase in a Decade.*	*Rate of Increase.*	
1682					Philadelphia settled by William Penn.
"					Middle Ferry over Schuylkill at High (Market) street, known as Gardener's.
1683	80	600			
1684	357	2500			
1685	600				
1692					Upper Ferry, or Scull's, started at "Fairmount."
1695					Ferry between Greenwich Point and Gloucester on the Delaware.
1696					Lower or Gray's Ferry over the Schuylkill.
"					Gray's Ferry Road authorized to be opened from Cedar Street to Darby Road; known as the King's Great Road.
1700	700	5000			
1703					Haverford Road from Upper (Powel's) Ferry authorized in June.
1707-8					Righter's Ferry was started at Manayunk.
1727					Cooper's Ferry to Cooper's Point, N. J., chartered August 18th.
1731		12240			STAGE LINE from Burlington to Amboy, N. J.
1732					
1744	1500	13000			
1749	2076	15000			
1750					Penrose Ferry marked as a "ford" on maps.
"					Garrigue's Ferry, below the "Falls," also one just above mouth of Wissahickon started (often forded).
1752					The Burlington and Amboy Stage Line *via* Bordentown (bi-weekly).
1753	2300	14563			Rival stage lines and one through line to New York in three days.
1757					Other lines from Burlington to Amboy.
"					Stage line to Annapolis *via* Reedy Island and Fredericktown.
1759					Stage line from Cooper's Point to New York *via* Mount Holly (three days).
1760					Stage line to Baltimore *via* New Castle, Elk River and the Chesapeake (about five days).
1760	2969	18756			CONESTOGA WAGONS first used.
1761					Stage, Philadelphia to Germantown three times a week.
1762					Rival stages from Cooper's Point to New York.

1762					Survey by Provost Smith and David Rittenhouse for canal from the Schuylkill to Lake Erie and the Ohio River.
1764					Survey ordered by American Phil. Society for Delaware and Chesapeake Canal.
1766					No regular stage line to the West.
"					The stage "Flying Machine" reduced the time to New York to two days.
1769	4474	28042			
1771					Time to New York reduced to one and a half days by stage.
1772					A third flying coach started *via* Princeton.
1776	5460	40000			Lord Howe's enumeration (except of army and strangers). Revolution.
1776-7					Floating bridge over Schuylkill built by General Putnam.
1777	5470	21767			British occupancy from September, 1777, to June, 1778.
"					British built a floating bridge at Gray's Ferry, October 20th; destroyed October 28th.
1783	6000	37000			Close of Revolution.
1784					Stage to Lancaster by Fred. Schaeffer; round trip, three days.
1786					A post route opened to Pittsburgh.
"					Old floating bridge at Middle Ferry rebuilt.
"					John Fitch's skiff propelled by steam on the Delaware, July 20th; not very successful.
"	6400	32205			Census as given by New York Gazette.
1787					John Fitch's boat 45 feet long, 12″ cylinder, successful August 22d.
"					Springs for wagons first introduced.
1788					One of Fitch's steamboats ran to Burlington at rate of four miles per hour.
1789					All of the floating bridges carried away by a flood.
"					Stage line to Reading; time, two days; fare, two dollars; letters, three pence.
1790	6651	54391			Larger steamboat to Burlington, eight miles per hour; ran 3000 miles that season.
1792					Delaware and Schuylkill Canal incorporated April 10th.
"					First TURNPIKE in the United States, Philadelphia and Lancaster, commenced.
"					United States Mint established at Philadelphia.
1793					Yellow fever in Philadelphia; 4002 deaths.
1794					District of Southwark incorporated April 18th.
1795					Lancaster Pike completed by private company; cost, $465,000.
1796					Four daily stages to New York; one daily to Baltimore, and once or twice a week to Lancaster, Wilmington, Dover, Harrisburg, Reading and Easton.
1797					A side-wheel boat ran on Delaware River to Bordentown.
"					1292 deaths from yellow fever.
1798					Permanent bridge company organized; capital, $150,000. Ferry sold for $40,000.
"					3637 deaths from yellow fever.
1799					1015 deaths. WATER WORKS at Chestnut Street wharf, on Schuylkill, and at Centre Square built.
1800	11200	81009	26618	49.0	Stage line from Philadelphia to Long Branch. Corner-stone of permanent bridge laid, October 18th.

Year.	Number of Houses.	Population City and County.	Increase in a Decade.	Rate of Increase.	
1800					Germantown and Perkiomen Pike and Schuylkill Arsenal built.
1801					First water pumped at Centre Square, January 21st. United States Navy Yard established.
1802					835 deaths from yellow fever.
1803					The Cheltenham and Willow Grove Pike commenced. Northern Liberties incorporated.
1804					The permanent (Palmer's) bridge completed. Opened January 1st, 1805.
"					Oliver Evans launched a stern-wheel boat, which ran 16 miles an hour.
"					Philadelphia, Bristol and Morrisville Pike commenced.
"					The Chestnut Hill and Spring House Pike commenced.
"					First line of stages to Pittsburgh (through in seven days) began in August.
1805	13461				
1806					Attempt to incorporate Gray's Ferry Bridge Company at lower ferry.
1807					The Phœnix steamboat, by J. C. Stevens, put in operation. Arch Street Prison built.
1809					Chain bridge by Kennedy & Carpenter built at Falls of Schuylkill.
"					First TRAMROAD in America built at Leiper's quarries.
"					The Phœnix ran regularly to Bordentown till 1813.
1810	16682	111210	30201	37.3	The Philadelphia, Brandywine and New London Pike commenced.
"					The second permanent bridge in the county built at Flat Rock, over Schuylkill River.
"					Floating bridge at Fairmount again destroyed.
"					The built up part of city, including suburbs, extends three miles along Delaware and one miles west.
1811					Another bridge at Falls authorized. Chain bridge broke down.
"					Perkiomen and Reading Pike commenced.
1812				War with Gt. Britain.	Wernwag's bridge Colossus begun at Fairmount, April 28th. Moyamensing incorporated.
"					March 24th, War of 1812. The Ridge Turnpike commenced.
"					Steamboat New Jersey started on Delaware River.
1813					Spring Garden incorporated March 22d. Steamboat Eagle started in June.
1814					The Spring House and Bethlehem Turnpike commenced.
1816					White & Hazard built the first WIRE bridge (in the world) at Falls; cost, $125.
1817					A wooden bridge completed at Falls late in year.
"					Steamboat Ætna, owned by Jos. Bonaparte, ran from Philadelphia to Baltimore.
1819					FAIRMOUNT WATER WORKS commenced; completed in 1822.
1820	20565	135637	24427	22.	Up to this time largest city in United States. Kensington incorporated March 6th. Yellow fever, 67 deaths.
1823					Corner-stone of Eastern Penitentiary laid May 22d.

1825					Corner-stone of United States Mint laid July 4th.
"					Schuylkill Navigation CANAL completed and opened.
1827					Union Canal opened December 30th.
1829					New bridge built at the Falls.
"					Delaware and Schuylkill Railroad Company chartered under title of Northern Liberties and Penn Township.
1830	27968	188797	53160	39.2	Surveys begun on Camden and Amboy Railroad.
1831					Philadelphia, Germantown and Norristown Railroad chartered February 17th. West Chester Railroad February 18th.
"					First report Camden and Atlantic Railroad made in June. The "Boxall" stage ran on Chestnut street December 7th; soon after discontinued.
1832					Corner-stone of Merchants' Exchange laid February 22d.
"					Philadelphia and Trenton Railroad incorporated February 23d.
"					Manayunk Bridge Company incorporated March 24th.
"					Corner-stone of Moyamensing (county) Prison laid April 2d; finished 1835.
"					Two pleasure cars ran in May on Columbia Railroad as far as Lemon Hill, near Fairmount.
"					Car put on Philadelphia and Columbia Railroad, by proprietors of stage line, to Pittsburgh.
"					Philadelphia, Germantown and Norristown Railroad opened to Germantown, June 6th. Cars drawn by horses. Locomotives in Fall.
"					July 5th to October 4th, 935 deaths from Asiatic cholera.
"					LOCOMOTIVES FIRST TRIED between Broad Street and the Schuylkill, on Columbia Railroad, in September.
"					Part of West Chester Railroad opened September 13th to junction with Columbia Railroad.
"					Car ran from Broad and Callowhill to Paoli, Chester County, in September; Schuylkill River crossed by ferry.
1833					Steamboat Trenton began running January 22d.
"					Camden and Amboy Railroad finished in January between Bordentown and Amboy.
"					Philadelphia and Reading Railroad chartered April 4th.
"					The second permanent bridge was broken down September 19th.
"					Canal built at west end of permanent bridge.
"					OMNIBUS line from Coffee House to Fairmount, every half hour. Other lines.
"					Girard College commenced.
"					Manayunk Bridge at Righter's Ferry finished.
"					Broad Street Railroad from Vine to Cedar (South) finished and opened December 9th.
"					Philadelphia and Columbia Railroad opened as far as West Chester December 25th.
1834					Columbia Bridge opened in March. Reading Railroad Bridge at Falls.
"					Philadelphia and Columbia Railroad opened to Columbia in April.
"					Delaware and Schuylkill Railroad opened from Broad Street to the Delaware in April.

Year.	Number of Houses.	Population City and County.	Increase in a Decade.	Rate of Increase.	
1834					Norristown branch of Philadelphia, Germantown and Norristown Railroad opened to Manayunk October 18th.
"					Philadelphia and Trenton Railroad completed November 1st.
"					Cars began running regularly to Peter's Island.
"					United States mail to New York *via* Camden December 29th.
1835					Depot at Willow Street wharf completed in January. Delaware and Schuylkill Railroad.
"					Camden and Amboy Railroad fully opened in the Spring. Stages soon after removed. Gas works authorized.
"					Philadelphia and Reading commenced in September; completed July, 1838.
"					Cars and boats ran through to Pittsburgh in three and a half days.
"					Norristown branch Philadelphia, Germantown and Norristown Railroad completed August 15th.
"					Tramways to bring freight to business part of city authorized in November.
1836					PHILADELPHIA GAS WORKS opened February 8th. Laurel Hill Cemetery laid out.
"					Name of Philadelphia and Delaware County Railroad changed to Philadelphia, Wilmington and Baltimore Railroad.
1837		Financial Crisis.			Philadelphia, Wilmington and Baltimore Railroad opened from Wilmington to the Susquehanna May 5th.
1838					Riots. Upper Ferry (Fairmount) Bridge burned.
"					Portions of Philadelphia and Reading Railroad opened.
"					Philadelphia, Wilmington and Baltimore Railroad Bridge at Gray's Ferry; cost, $200,000, with rights.
"					Monument Cemetery (Broad and Norris Streets) laid out.
1838-9					Canal cut through Smith's Island.
1839					Gray's Ferry Bridge partially destroyed by freshet January 27th.
"					A bill authorizing free bridges passed March 16th. Gray's Ferry Bridge made free.
1840	53078	258037	69240	36.5	High Street permanent bridge sold to city for $80,000 and made free.
"					Track of Philadelphia and Trenton extension down Front Street torn up by a mob.
1841					The Philadelphia and Reading Railroad opened to the coal fields.
"					The Philadelphia and Reading Railroad opened from Pottsville to Peter's Island.
1842					Wire bridge by Ellett opened at Fairmount January 2d.
"					Philadelphia and Reading Railroad opened a wooden bridge at the Falls January 10th.
"					Reading Railroad and old Falls bridges burned August 26th.
"					Depot of the Philadelphia, Wilmington and Baltimore Railroad established at S. E. corner Eleventh and Market street.
				Mexican War.	

1842					Richmond branch Reading Railroad built (five miles).
1843					Old Red Bridge at Falls built.
"					A stone bridge begun at Falls.
1844					West Philadelphia incorporated.
"					Spring Garden and Northern Liberties Water Works opened for use.
1846					Pennsylvania Railroad Company incorporated April 13th.
"					Lehigh Valley Railroad incorporated as the Delaware, Lehigh, Schuylkill and Susquehanna Railroad Company.
1847					Charter issued to Pennsylvania Railroad Company February 25th. Work begun west of Harrisburg, July 16th.
1849					Permanent bridge remodelled for Pennsylvania Railroad.
"					1012 deaths from cholera. Great fire, 367 houses burned, July 9th.
"					61 miles of Pennsylvania Railroad opened to Lewistown.
1850	61278	408762	150725	58.5	Philadelphia and Reading Company bought the Philadelphia and Columbia Railroad from Broad and Vine Streets to Belmont.
"					The Pennsylvania Railroad was connected with the inclined planes over Allegheny.
"					Surveys of Lehigh Valley Railroad commenced.
1851					Work on Lehigh Valley Railroad commenced in Spring.
1852					Act authorizing Girard Avenue Bridge passed March 27th; to cost $175,000.
"					North Pennsylvania Railroad Company started April 8th.
"					Large station Broad and Prime (Washington Avenue) finished for Philadelphia, Wilmington and Baltimore Railroad.
"					Chestnut Street Bridge authorized.
"					Cars through from Philadelphia to Pittsburgh December 10th.
1853					West Chester and Philadelphia and Baltimore Central chartered March 17th.
"					Lot at Thirteenth and Market Streets ("Grand Depot") purchased for freight station by Pennsylvania Railroad.
1854					Horse Shoe route over mountains opened February 15th. Portage abandoned.
"					City and suburbs incorporated.
"					Passenger depot Pennsylvania Railroad was at Eleventh and Market Streets, formerly Philadelphia, Wilmington and Baltimore.
1855					North Pennsylvania Railroad opened to Fort Washington July 2d.
"					Lehigh Valley Railroad finished September 24th.
"					Girard Avenue (wooden) bridge finished.
1857					Chestnut Street Bridge commenced. Financial crisis.
"					North Pennsylvania Railroad opened through to Bethlehem.
"					Philadelphia and Derby Street Car Line incorporated April 28th.

Year.	Number of Houses.	Population City and County.	Increase in a Decade.	Rate of Increase.	Total No. Passengers Reported as Carried.	
1858						Fifth and Sixth Street Line first in operation, Frankford to Southwark, January 20th.
"						Second and Third Street Line chartered April 10th.
"						West Philadelphia Company began running on Market Street in July.
"						Tenth and Eleventh Street (Citizens') began running July 29th.
"						Race and Vine began running September 8th (Hestonville).
"					No report.	Spruce and Pine (Gray's Ferry) began running December 4th.
1859						Fairmount Passenger Railway Company chartered April 6th.
"						Girard College (Ridge Avenue) began March 14th.
"						Girard Avenue (Richmond and Schuylkill) chartered March 26th.
"						Arch Street Line (Hestonville, Mantua and Fairmount) opened June 23d.
"						Chestnut and Walnut Street (Philadelphia Company) Line opened to Twenty-second Street October 24th.
"						Germantown Line opened in Summer.
"						Green and Coates Street Line opened in Summer.
"						Ridge Avenue and Manayunk branch opened.
"						Thirteenth and Fifteenth Street Line chartered.
"						Seventeenth and Nineteenth Street Line opened.
"						Washington Avenue wharf on Delaware terminus of Pennsylvania Railroad for freight.
1860	89979	565529	156767	38.5	7267000	Bridge at Penrose Ferry made free. Area of built up part of city = 7.01 square miles.
1861						Lombard and South Street Line chartered May 16th.
"					16523085	Navy Yard, Broad Street and Fairmount chartered May 16th.
1862					20865388	Junction Railroad opened January 27th. Wissahickon Bridge, Philadelphia and Reading Railroad, burned August 12th.
1863					26663460	West end of Gray's Ferry Bridge burned.
1864						Seventh and Ninth Street Line chartered April 8th (Union Line).
"						Station of North Pennsylvania Railroad moved from Front and Willow to Germantown Avenue and Thompson, and later to Berks and American.
"					29813710	Pennsylvania Railroad passenger depot moved to Thirteenth and Market, later to Thirty-second and Market.
1865						
					25043398	City Passenger Railway fares raised from five to seven cents.
1866						Wissahickon, Roxborough and Plymouth Railway chartered April 8th.
"						Schuylkill River Railway (Twenty-second and Twenty-third Streets) chartered April 16th.
"						Chestnut Street iron arch bridge opened June 23d.

(Civil War.)

1866						Street cars ran west over bridge as early as May 13th.
"					30919120	North Broad opened, Nicetown to Fisher's Lane, December 14th.
1867					25762453	No report from Thirteenth and Fifteenth, Seventeenth and Nineteenth, Union, West Philadelphia, and Ridge Avenue.
1868					39870612	No report from Ridge Avenue, Green and Coates, and West Philadelphia.
1869					49994497	No report from Ridge Avenue, Green and Coates.
"						Philadelphia, Germantown and Norristown Railroad depot, at Ninth and Green, burned.
"						Empire Line (Twelth and Sixteenth) chartered February 10th.
1870	112366	674022	108493	19.3	55400926	The Philadelphia and Reading Railroad Company leased the Schuylkill Navigation Company's canal, etc.
1871					58448290	All lines reported.
1872					66781414	Philadelphia and Reading Railroad Company leased the Susquehanna Canal January 1st.
"	124302					Grand Jury condemned Girard Avenue Bridge December 16th.
1873						People's Line (Callowhill Street) chartered April 15th.
"						West End Line (in West Philadelphia) chartered April 15th.
"	134740	726144			73771995	Continental Line (Eighteenth and Twentieth) chartered September 8th.
1874						New iron bridge, 100 feet wide, opened, Girard Avenue, July 4th.
"					78508235	The Keystone Bridge Company built the iron bridge at Fairmount.
1875						Market Street Bridge destroyed by fire.
"						South Street Bridge opened for pedestrians November 30th.
"					87387331	Pennsylvania Railroad Company built Howe truss at Market Street in December.
1876	143936	817448	Centennial		117795833	South Street Bridge fully opened February 17th.
"						Continental and People's Line began running.
"						"The thickly built up city extends from Mifflin Street to Allegheny Avenue and from Delaware to Schuylkill."
1877					89588128	Seven steam dummies ran on Market Street March 21st.
"						Philadelphia and Atlantic City Railroad opened July 8th.
1878					88170981	Another bridge at Penrose Ferry completed January 20th.
1879					90824855	North Penn, Delaware and Bound Brook opened in May.
1880		847170	173148	25.7	99045515	
1881					104370300	Filbert Street Bridge (Pennsylvania Railroad) opened. Elevated road completed, and depot removed to Broad and Filbert February 16th.
"						Philadelphia, Wilmington and Baltimore Railroad bought by Pennsylvania Railroad for $16,675,692.
1882					109455040	
1883					112359552	

XII.

REMOVING CONDEMNED MACHINERY BY DYNAMITE.

By J. J. de Kinder, Member of the Club.

Read May 17th, 1884.

The old side lever Cornish pumping engine at the Spring Garden Pumping Station was sold a short time ago by the Philadelphia Water Department for scrap.

The purchasers consented to let the Water Department remove it at their (the purchasers') expense, as the Department insisted that it should be removed with the least possible delay, requiring the floor space occupied by the engine for other use. The machinery is very heavy, the steam cylinder being 80 inches in diameter by 10 feet stroke.

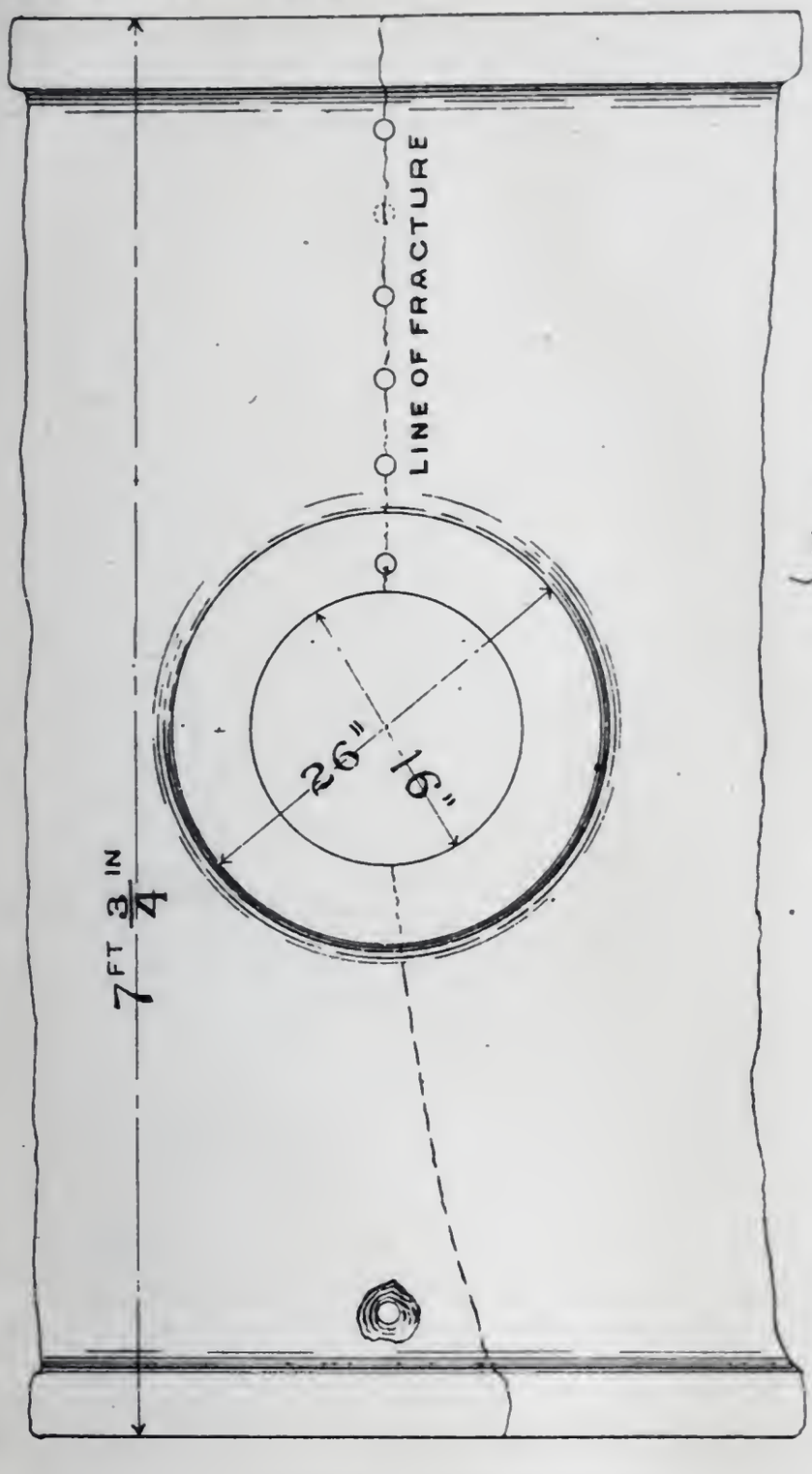
The most troublesome job was the removal of the side levers, the two levers weighing 57,000 lbs. or 28,500 lbs. apiece. They were keyed on a 15-inch shaft, and as there was no room to drive the keys back, and they would not draw by means of a bolt and clamp, it was determined to break the beams in two.

As the annexed sketch shows, the beams have a sectional area each of 509 sq. in., and are 7 feet deep. There were drilled in each beam a line of 1 inch holes above the shaft through the centre line, and a hole, $1\frac{1}{4}$ diameter by $15\frac{1}{4}$ inches deep, parallel to the shaft, into the hub of the beam, tapped a thread about $2\frac{3}{4}$ inches deep into this last hole, filled the hole with half a pound of dynamite, and screwed a plug hard up on top of it. There having been made provisions for entering the fuse by previously (before tapping the thread) cutting a groove $\frac{1}{4}$ deep with a cape chisel in the bottom surface of the hole, and entering it about 3 inches, just sufficient to clear the bolt.

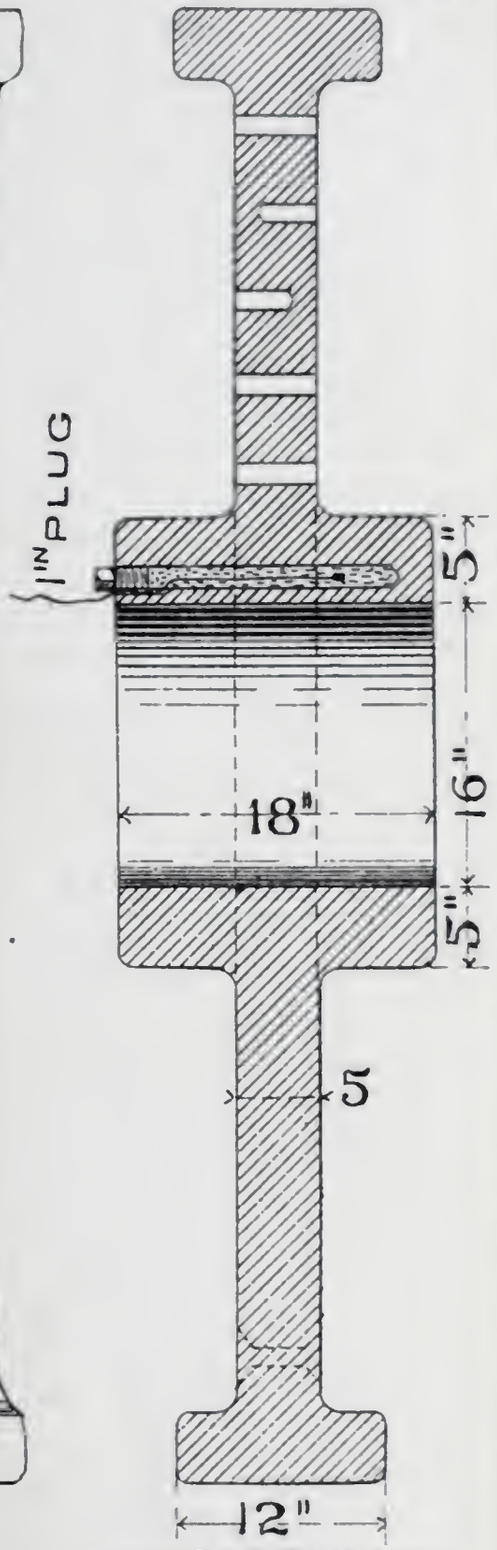
The engine stood inside of a building having stone walls of about $2\frac{1}{2}$ feet thick and built in a very indifferent manner, and windows completely surrounded it on two sides.

When the charge was carefully prepared, and precautions, which were thought necessary to protect the other machinery in the building, taken, the windows and doors were opened and the charge exploded.

PROC. ENG. CLUB OF PHILA., 1884.
VOL. IV, NO. 3. PLATE X.



— SIDE ELEVATION. —



— SECTION —

REMOVAL OF BEAM

SPRING GARDEN PUMPING STATION,

PHILADELPHIA.

AREA OF BEAM,	509 SQ. IN.	TENSILE STRENGTH OF CAST IRON,	18,000 LBS.
AREA OF HOLES,	48 " "	ULTIMATE STRENGTH OF BEAM,	8,298,000 "
REMAINING AREA,	461 " "	CHARGE, 1-2 LB. ATLAS POWDER No. C, AND COMMON FUSE.	

GENERAL MAP
OF THE
ANTHRACITE COAL FIELDS
OF
PENNSYLVANIA
AND
ADJOINING COUNTIES.
CHAS. A. ASHBURNER, GEOLOGIST IN CHARGE
1884.
LEGEND.
Coal Measures No XIII and Pottsville Conglomerate No XII.
Top of Mauch Chunk Red Shale No XI
WESTERN NORTHERN COAL FIELD
EASTERN MIDDLE COAL FIELD
WESTERN MIDDLE COAL FIELD
SOUTHERN COAL FIELD
AREA OF ANTHRACITE FIELDS
(Approximate)
Western Northern (Unknown)
Northern 200 Sq. Miles
Eastern Middle 40 "
Western Middle 90 "
Southern 140 "
Total Area 470 "
Julius Bien & Co Lith
Scale of Miles
Scale of Kilometers

The result was a sharp report—no damage whatsoever to walls or windows or any other part of the building—and the beam broken clean in two pieces; the same operation was then repeated on the second beam with the same result.

The time required for drilling holes, tapping, charging, etc., was about 13 hours for each beam.

XIII.

BRIEF DESCRIPTION OF THE ANTHRACITE COAL FIELDS OF PENNSYLVANIA.

By Charles A. Ashburner, Member of the Club.

Read by Title, June 21st, 1884.

GEOGRAPHY.

The anthracite region is situated in the north-eastern part of Pennsylvania, between the Washington meridian and that 1° 10′ east and the north parallels of 40° 25′ and 41° 40.′

It is divided into the following prominent divisions: (1) Southern or Pottsville Field, extending from the Lehigh River at Mauch Chunk, south-west to within a few miles of the Susquehanna River, directly north of Harrisburg, and embraced by Carbon, Schuylkill and Dauphin Counties. The eastern end of this field, known as the Lower Lehigh or Panther Creek basin, between Tamaqua on the Little Schuylkill River and Mauch Chunk, has generally been included by the coal trade in the Lehigh Field, from the fact that its coals resemble more closely the coals obtained in the Upper Lehigh region than those in the Pottsville Field west of Tamaqua, and since the shipments to market have almost entirely been made through the Lehigh Valley. (2) Western Middle or Mahanoy and Shamokin Field, lying between the eastern-most head-waters of the Little Schuylkill River and the Susquehanna River and within Schuylkill, Columbia and North-

Notes.—This brief description was prepared by the author for the Proceedings of the Club in anticipation of the excursion through the Anthracite region on September 6th, 1884, tendered by the Philadelphia and Reading and Lehigh Valley Railroads to the members of the American Institute of Mining Engineers, American Association for the Advancement of Science, British Association for the Advancement of Science, and other foreign societies. Reference has only been made to those features which, it was thought, would be of especial interest on this occasion.

The black base of the accompanying map was printed from an engraved stone in the possession of the Second Geological Survey, by permission of the Board of Commissioners.

umberland Counties. These two coal fields (1 and 2) are frequently designated in a general way as the Schuylkill region, although parts of them are better known to the trade by names defining districts from which coals of special characteristics are mined. (3) Eastern Middle, or Upper Lehigh Field, lying between the Lehigh River and Catawissa creek and principally in Luzerne County, with limited areas extending into Carbon, Schuylkill and Columbia Counties. (4) Northern or Wyoming and Lackawanna Field, lies in the two valleys from which it derives its geographical names, and is embraced almost entirely by Luzerne and Lackawanna Counties. A small area in the extreme north-eastern end of the field extends into Wayne and Susquehanna Counties. (5) Loyalsock and Mehoopany Field,* lies within the area drained by the head-waters of the Loyalsock and Mehoopany creeks, and is contained in Sullivan and Wyoming Counties. This field is from twenty to twenty-five miles north-west of the western end of the Northern Field. Its geological structure resembles more closely that of the bituminous field, in which it has until recently been included, although the composition of many of its coals entitles them to rank with a number from the anthracite region.

The area of the region is about 1700 square miles. The natural geological and topographical boundaries of this area are formed by the mountains and ridges made by the Pocono sandstone No. X; although, no workable coal beds have been found stratigraphically below the Pottsville conglomerate No. XII, the Lykens Valley or lowest anthracite beds being found in the latter formation. The greatest length of the region, from the north-eastern end of the Northern Field to the south-western end of the Southern Field, is about 115 miles, while the greatest width of the belt, containing the first four fields, is about 30 miles between Mauch Chunk and Shickshinny, near western end of the Northern Field.

The approximate areas underlaid by workable beds in the different fields are as follows:

Northern	200 square miles.
Eastern Middle	40 " "
Western Middle	90 " "
Southern	140 " "
Loyalsock and Mehoopany	Unknown.
Total	470 " "

* It has been suggested that this field be called the Western Northern (see map).

HISTORY.

The first record we have of the practical use of Pennsylvania anthracite is in 1768 and 1769, when it was employed for blacksmithing by two brothers named Gore, who had moved from Connecticut and settled in the Wyoming Valley near Wilkes Barre. This was possibly twenty years subsequent to the commencement of coal mining in the United States, in the Mesozoic bituminous basin in the vicinity of Richmond, Virginia.

In 1775 it is reported that a cargo of coal was shipped in flat-boats from Wilkes Barre down the Susquehanna to the government armory at Carlisle.

The first organized effort for the mining of coal was in 1793, when the Lehigh Coal Mine Company was organized, and purchased land at Summit Hill, nine miles from Mauch Chunk, from Mr. J. Weiss. The Mammoth bed had been accidently discovered on this land in 1791. In 1803, this company loaded six flat-boats or river-arks, holding about 10 tons each, and started them down the Lehigh River for Philadelphia; only two of these boats reached destination. No one knew how to burn the stone-coal and it was considered worthless. In 1814 another shipment of five arks was made in the same way, two of them reaching Philadelphia, the coal which they contained being sold to White & Hazard at the Falls of the Schuylkill. This latter shipment was preceded two years (1812) by nine wagon-loads of coal, hauled to Philadelphia from the Schuylkill region.

It appears that Judge Fell, of Wilkes Barre, first used anthracite coal as a household fuel. In a memorandum dated Feb. 11th, 1808, he says, "made the experiment of burning the common stone-coal of the valley, in a grate, in a common fire-place in my house, and find it will answer the purpose of fuel, making a clearer and better fire at less expense than burning wood in the common way."

The first use of anthracite, in connection with the manufacture of iron, dates from 1812, when White & Hazard purchased one of the nine wagon-loads from the Schuylkill region at the cost of transportation, and successfully used the coal in heating the furnace of their nail and wire mill at the Falls of the Schuylkill.

The regular shipment of anthracite coal to market, however,

did not commence until 1820, during which year the Lehigh Coal and Navigation Company sent 365 tons from their famous mine at Summit Hill to Philadelphia. In 1822 the Schuylkill region is reported to have first shipped to market 1480 tons. In 1829, 7000 tons were first shipped from the Wyoming region by the Delaware and Hudson Canal Company, whose canal had just been completed; the aggregate shipment from the entire region during the latter year being 112,083 tons.

Anthracite for the generation of steam was first employed in January, 1825, under the boiler of Thompson's rolling mill at Phœnixville.

The first successful use of anthracite, as an exclusive fuel in the blast furnace, was at the Pioneer furnace, built during 1837 and 1838 at Pottsville by William Lyman, of Boston. The first successful blast was blown in at this furnace on October 19th, 1839. In recognition of the results obtained in this furnace, Mr. Lyman was paid a premium of $5,000 by Nicholas Biddle and others, as being the first person in the United States who had made anthracite pig iron continuously for one hundred days. As early as 1824 attempts had been made to use anthracite in charcoal furnaces, mixed with charcoal; this and many subsequent attempts prior to 1839 seem to have all met with failure. On July 3d, 1840, Mr. David Thomas successfully blew in a furnace which he had built for the Lehigh Crane Iron Company at Catasauqua, on the Lehigh River. Previous to this time Mr. Thomas had been associated with Mr. Crane in his experiments at Yniscedwin. The Catasauqua furnace was in active operation until 1879, when it was torn down.

The First Geological Survey of this region by the State, was commenced in 1836, and was continued at intervals until the publication of the final Report of the First Survey in 1858. The results of this survey were in the highest sense valuable; they are being supplemented, rather than replaced, by the more detailed and practical work of the Second Survey.

The Second Survey was commenced in August, 1880, and has been vigorously prosecuted since that time. The principal object of this Survey has been to make the results practically useful to those directly interested in the exploration and exploitation of

the coal fields. About one-third of the area of the region has been mapped by the survey, although the work cannot be said to be one-third completed, since the geology of the area not yet examined and surveyed is more difficult and less developed than that of the area already covered.

These few facts connected with the early history and development of anthracite coal are interesting, when it is considered that the mining and transportation of Pennsylvania anthracite is the most important industry connected with the development of any mineral, in any one State in the Union.

TOPOGRAPHY.

The grand features of the topography of the region have been determined by its structural geology. These consist of two distinct series of ridges or mountains, one formed by the Pottsville conglomerate, and the other by the Pocono sandstone; and two series of valleys, that eroded out of the coal measures, surrounded by the Pottsville conglomerate ridges, and that cut out of the Mauch Chunk red shale No. XI, which lies between the two series of ridges. The Pottsville conglomerate mountains rise from eight hundred to one thousand feet above their bases, while the Pocono mountains are generally, though not always, higher. The difference between the extremes of elevation within a radius of twenty-five miles rarely exceeds fifteen hundred feet, while that between the extremes within a compass of two or three miles seldom amounts to more than one thousand feet. In speaking of these grand features, Professor Lesley says, "Each coal basin is set in a double frame, being limited by a mountain of conglomerate, outside of which runs a narrow valley or trough of red shale, outside of which again runs a second and still higher mountain of white sandstone, the outside flank of which is always furnished with a terrace of red sandstone." The surface of the valleys underlaid by the coal measures is undulated by small ridges, which are formed by the harder sandstones contained in the intervals between the coal beds. The coal beds themselves frequently form terraces along the slopes of the ridges, which permit of the coal beds being easily traced, in many localities over considerable areas. The most

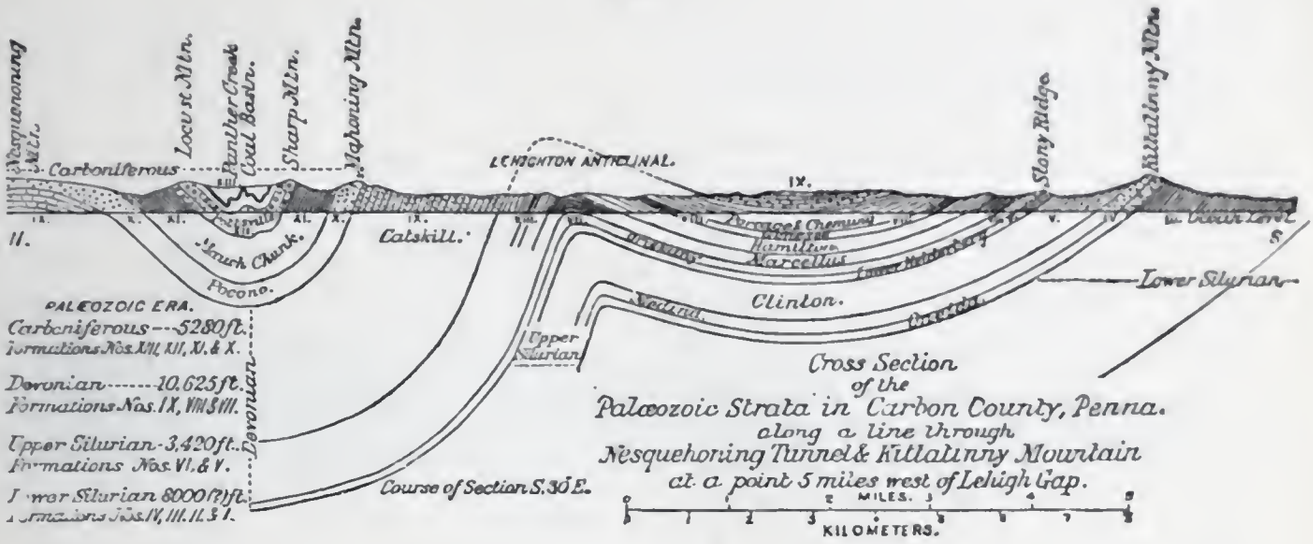
prominent of these ridges seldom rise to a height more than half of that of the enclosing Pottsville conglomerate mountains. The Broad Mountain plateau, separating the Western Middle and Southern Fields, and ranging about five miles wide and fifteen miles long, the Upper Lehigh Mountain plateau, containing the coal basins of that region, and ranging about eight miles wide and fifteen to twenty miles long, and the Nescopec Mountain plateau, which crosses the Lehigh Valley and Lehigh and Susquehanna Railroads between White Haven and the southern rim of the Wyoming Valley, are exceptions to the usual sharp profiles of the Pottsville and Pocono mountains. A general idea of the height of the region and surrounding areas above ocean level may be had from the following elevations of prominent points:

Harrisburg (P. R. R. depot) . . .	321	Tamaqua (P. & R. R. R. depot) .	803
Northumberland	452	Mahanoy City	1343
Catawissa	477	Shenandoah	1252
Shickshinny	521	Gilberton (P. & R. R. R. depot) .	1133
Nanticoke	538	Ashland	859
Wilkes Barre (L. & S. R.R. depot)	550	Mount Carmel	1054
Pittston (L. V. R. R. depot) . .	571	Shamokin (P. & R. R. R. depot) .	738
Scranton (D. L. & W. R. R. depot)	739	Mauch Chunk (L. V. R. R. depot)	544
Port Clinton	410	Hazleton (L. V. R. R. depot) . .	1612
Schuylkill Haven	526	Drifton (L & S. R. R. depot) . .	1633
Pottsville	614	White Haven (L. V. R. R. depot)	1143
Tremont	766	Upper Lehigh	1802

STRUCTURAL GEOLOGY.

All the rocks found in, or immediately surrounding the anthracite region, are sedimentary, belong to the Palæozoic era, and are highly corrugated. These strata, which after their deposition were comparatively horizontal, have been thrown into the deformations, in which we now find them, by the secular cooling and consequent contraction of the earth's surface, after the close of the Palæozoic time. The prominent features in the structure of this portion of the State are illustrated by the accompanying vertical cross-section (Fig. 1).

Fig. 1.



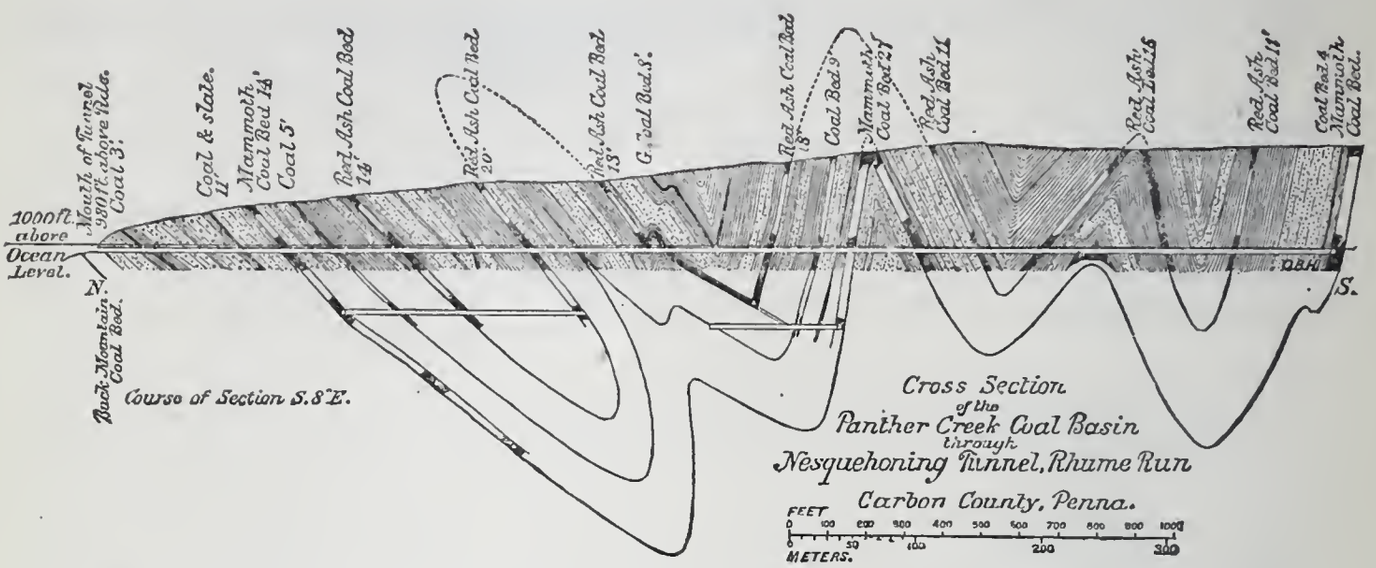
The denudation of the surface of the region by the natural eroding agents, which are still at work in a greater or less degree, has been very great, after the strata were upheaved and corrugated. From the top of Kittatinny mountain has been cut away all the strata included between the Medina sandstone (part of No. IV) and the highest coal measures (part of No. XIII) in the Panther Creek basin, measuring in the aggregate over 18,000 feet, perpendicular to the bedding. If the dip of the strata, after the corrugation was effected and before denudation had perceptibly taken place, was the same along a vertical line through the mountain as it is now, then as much as four miles vertical thickness of strata have been eroded from the area now marked by the Kittatinny crest. This mountain is one of the boldest topographical features in the State. It extends from the Delaware Water gap, between New Jersey and Pennsylvania, southwest for 90 miles to a point in Franklin County twelve miles west of Chambersburg. The details of the structure, between that portion of the mountain,* included between the Lehigh and Susquehanna Rivers and Sharp Mountain, formed by the Pottsville conglomerate, No. XII, which skirts the southeastern limit of the Southern Field, is different in many places from that shown in the accompanying section; the general structure, however, varies little.

The northern end of the section through the Panther Creek coal basin has been enlarged (from scale of 3 miles to 1 inch,

* Approximately defined by the lower border line of the accompanying map.

$\frac{1}{190080}$ths of nature, to a scale of 800 feet to 1 inch, $\frac{1}{9600}$ths of nature) to illustrate some of the details of the structure of the anthracite basins (Fig. 2).*

FIG. 2.


1000ft. above Ocean Level.
N.
S.
Back Mountain Coal Bed.
Course of Section S.8°E.
Cross Section of the Panther Creek Coal Basin through Nesquehoning Tunnel, Rhume Run Carbon County, Penna.
FEET
METERS.

The Pottsville conglomerate (No. XII), underlying the productive coal measures, has been thrown into broad, regular, and generally symmetrical flexures, while the overlying softer measures, containing all the workable coals, except in those districts where the Lykens Valley beds have dimensions sufficient to be mined, are found conformable to subordinate flexures of three kinds: symmetrical (central anticlinal, Fig. 2), unsymmetrical (southern anticlinal), and reversed (northern isoclinal).† In the case of the unsymmetrical and reversed flexures, the plane passing through the axes of the flexures, as exhibited in the dif-

* The method which has been used for representing the coal beds and rock strata in this section is that which has been adopted by the author for the cross-sections of the Geological Survey, as follows: (1) Where a coal bed has been worked out in the plane of section it is shown by two lines, one at the top and the other at the bottom of the bed; (2) where the position of a coal bed is certainly known, but the coal has not been worked out in the plane of section, it is shown by a heavy black line; (3) where the position of a coal bed can only be approximately determined, with present available facts, it is indicated by a single line representing the bottom of the bed; (4) the rock strata are only shaded where their character is absolutely known. One of the primary objects of the Anthracite Survey has been to render the results of its work of practical utility, and this method of constructing the cross-sections renders them of the greatest value to those superintending the mining of coal.

† Through the region an isoclinal, or a flexure, where the strata appear to dip in one direction on either side of the axis, is generally called an overturn, or overturned anticlinal.

ferent strata, is generally inclined down and toward the area of maximum disturbance.

This area of maximum disturbance lies to the south-east of the anthracite region, in the vicinity of Kittatinny mountain and is co-extensive with it throughout the central part of the State, crossed not only by this Medina crest, but by the parallel mountains capped by the same formation, and constituting what are known as the Blue ridges* in Pennsylvania and the North mountains in Virginia. This inclining of the unsymmetrical and reversed flexures toward the north and north-west was formerly thought to be universal in the anthracite region; recently, however, a number of exceptions have been found in small anticlines and isoclines, which incline toward the south and south-east. In the case of the accompanying sections, the Lehighton anticlinal (Fig. 1) and Panther Creek isoclinal (Fig. 2) follow the general law of inclination.

The area of maximum folding and contortion of the coal bearing measures is in the Southern Field, where the occurrence of isoclinals and sharp, narrow anticlinals and synclinals is more frequent. In the other fields the flexures gradually become flatter, broader, and further apart toward the north-west. The structure in the Eastern Middle Field is an apparent exception: when it is remembered, however, that in this district the flexures in the coal measures are found at a much greater height above ocean level, and the coal basins are generally much shallower than in the Southern Field, the general conclusion holds true, for the most complicated structure is invariably found in the bottoms of the coal basins, where the squeezing of the strata was the greatest during the original plication.†

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* The structure of these mountains and ridges is illustrated by numerous cross-sections constructed by the author in 1874 and '75 and contained in Report F, Sec. Geol. Sur. of Pa.

† The difficulties which have been encountered in mining near and in the bottoms of the Lehigh basins, foreshadow the greater irregularities of structure, which will probably be met with in mining in the bottoms of the Southern Field basins. Although the details of structure are rarely duplicated in different districts, yet I believe a careful mapping and study of the structural geology of the Lehigh basins will aid materially in the most economical development of the deeper portion of Southern Field basins.

The Northern Field, which is further removed from the area of maximum disturbance, is composed of a broad, canoe-shaped basin with moderate dips, the surface of any one of the coal measure strata, in general, being but slightly undulated by broad, low anticlinals and shallow synclinals, while the structure of the Loyalsock and Mehoopany Field,* which is still further removed, is identical with that of the Pennsylvania bituminous field; the average maximum dips of the coal bed ranging from between 3 and 5 feet to 100 feet.

Some idea may be had, from the following table, of the depths of some of the anthracite basins in which information has been obtained, of a sufficiently definite character, to permit of estimates being made. The elevations are given in feet above ocean level:

NORTHERN FIELD, WILKES BARRE BASIN.

	FEET.
Wilkes Barre (L. V. R. R. depot), ...	+549
Mammoth bed outcrop on north side of basin, at Kingston Coal Company's slope, No. 2, . .	+788
Mammoth bed outcrop on south side of basin, at Hollenback slope, No. 2, ...	+774
Bottom of Mammoth bed basin under flat, north of Wilkes Barre (estimated), ...	— 800
Depth attained by workings at Prospect colliery, .	— 300±

Width of basin, 23,200 feet (4.4 miles).

EASTERN MIDDLE FIELD, DRIFTON BASIN.

Drifton (L. and S. R. R. depot), ...	+1633
Buck Mountain bed outcrop on north side of basin, at Drifton slope, No. 2, ...	+1692
Buck Mountain bed outcrop on south side of basin,	+1645
Bottom of Buck Mountain bed basin, . . .	+1150

Width of basin, 2,250 feet (.4 miles).

HAZLETON BASIN.

Hazleton (L. V. R. R. depot), ...	+1612
Mammoth bed outcrop on north side of basin, .	+1660

* This field has been provisionally named, on the map, the Western Northern.

Mammoth bed outcrop on south side of basin, at Hazleton slope, No. 6, ...	+1672
Bottom of Mammoth bed basin, ...	+ 850

Width of basin along line through slope, No. 6, 3,800 feet (.7 miles).

Western Middle Field, Mahanoy Basin.

Gilberton (P. and R. R. R. depot), ...	+1133
Mammoth bed outcrop on north side of basin, at Gilberton slope, ...	+1223
Mammoth bed outcrop on south side of basin, at Draper slope, ...	+1275
Bottom of Mammoth bed basin, (estimated) . .	— 150

Width of basin along line through Gilberton slope, 3,050 feet (.6 miles).

Southern Field, Panther Creek Basin.

(Near Tamaqua.)

Tamaqua (P. and R. R. R. Depot), ...	+ 803
Mammoth bed outcrop on north side of basin, .	+1250±
Mammoth bed outcrop on south side of basin, .	+1300±
Bottom of Mammoth bed basin, (estimated) . .	—1000

Width of basin, 5,700 feet (1.1 miles).

The region is exceptionally free from rock faults. No downthrow or upthrow faults have been defined, such as are so frequently met with in the English coal field, where the hade of the fault makes an angle of more than 90 degrees with any one stratum on either side of the fault plane. The only breaks in the strata, which are worthy of mention in this brief description, are the fractures which occur along the reversed flexures, and which are properly called reversed faults. When the strata were corrugated and the overturns formed, the tension of the strata along the axis of the isoclinal was so great, that those on the upper side of the axial plane were shoved past those on the lower side;* these faults seldom amount to more than 300 or 400 feet, and in most cases where coal beds are enclosed in the faulted

* Faults of this character are illustrated, in the case of the Alps, by Heim, in his work on Mountain-making.

strata, the coal beds have been continued along the fracture or fault plane, but generally in a dirty, unworkable condition. Such faults have been encountered in the vicinity of Shenandoah, and along the south side of Bear Ridge, in Schuylkill County, and in the vicinity of Hazleton, Plymouth and Wilkes Barre, in Luzerne County.

STRATIGRAPHICAL GEOLOGY.

The rocks outcropping in the region are stratified and were deposited during the Palæozoic era.

The thicknesses of the several formations vary considerably along their outcrop in different portions of the field; their lithological characteristics are sufficiently constant, however, to permit of an easy recognition by the experienced geologist wherever they are exposed. The names of the periods and epochs under which these strata have been commonly grouped, with their accompanying thicknesses, as determined by the Geological Survey along the Lehigh River in Carbon County, south of the eastern end of the Southern Field (Fig. 1), are exhibited in the following table:

PALÆOZOIC ERA.

I. Carboniferous Period.

			FEET.
XIII.	Productive Coal Measures,		975
XII.	Pottsville Conglomerate (Seral, Millstone Grit),		880
XI.	Mauch Chunk Red Shale (Umbral),		2170
X.	Pocono Sandstone and Conglomerate (Vespertine),		1255

II. Devonian Period.

IX.	Catskill Sandstone (Ponent)		7145
VIII.	Chemung Shales and Sandstones,	Vergent	1290
	Portage Shales and Flags,		
	Genesee Slates and Shales,	Cadent	290
	Hamilton Sandstones and Flags,		760
	Marcellus Shales and Slates,		800
	Upper Helderberg Limestone,	Post Meridian.	Absent.
	Caudi Galli and Schoharie Grits,		
VII.	Oriskany Sandstone (Meridian),		340

III. Upper Silurian Period.

VI.	Lower Helderberg Limestones and Shales (Pre-Meridian), ...		295
	Onondaga Shales (Scalent), . . .		
V.	Clinton Red and Gray Shales (Surgent),		2000
IV.	Medina Sandstones,		665
	Oneida Sandstones and Conglomerates, . . .	Levant	460

IV. Lower Silurian Period.

III.	Hudson River Slates Utica Slates, . .	Matinal . .	6000±
II.	Trenton and Calciferous Limestones (Auroral),		2000±
I.	Potsdam Sandstone (Primal), . . .		——

The numbers assigned to the epochs and formations are those which were adopted by the First Pennsylvania Survey. The geographical names were first proposed by the New York State Survey, and have been generally made use of by geologists, wherever the strata composing these formations could be identified, throughout the Appalachian region. The New York nomenclature ended with the Catskill, and the names Pocono, Mauch Chunk, and Pottsville, were first suggested for the higher Pennsylvania rocks by Prof. Lesley, in 1875. The names placed in brackets were introduced by Prof. H. D. Rogers during the progress of the First Pennsylvania Survey. They have, however, never been generally adopted.

The areas in the region underlaid by the formations Nos. XII, XI and X, are generally easily defined by the topography which they produce, although in places no actual exposed outcrop may be found. The Pottsville conglomerate forms a rim around the coal basins, and the Pocono sandstone and conglomerate an outer rim, with a valley included between them eroded out of the Mauch Chunk red shale.

The thickness of the Pottsville conglomerate varies greatly. In Nesquehoning gap it measures 1155 feet (Fig. 3). Two miles to the east, midway between Nesquehoning gap and Mauch

Chunk, it is about the same thickness, while four miles to the west in the Nesquehoning Railroad tunnel* it measures only 880 feet, as given in the table of formations. In Locust Mountain gap, directly north of Tamaqua, about five miles a little south of west of the Nesquehoning Railroad tunnel, it measures 1280 feet. This variability in the thickness of the Pottsville conglomerate within short intervals, may show an unconformability between the underlying Mauch Chunk red shale No. XI (representative of the Sub-carboniferous or Mountain limestone), or an unconformability between the individual strata forming the conglomerate measures. It is more probable, however, that this change in thickness is due to an unevenness in the bottom of the water basin at the time that deposition took place, or to variable and changing water currents.

The facts at present obtained do not seem to be sufficient to attempt a final solution of the question. Prof. Lesley, in referring to this phenomenon, concludes that, "The variable thickness of the conglomerate must be discussed on one of two hypotheses: either, we must surmise extraordinary and unaccountable variations in the quantity of sand and gravel deposited on neighboring parts of the red shale sea bottom; or, we must apply the mechanical law, that the folding of a plastic mass shifts all parts of the mass to allow of its accommodation in a smaller space."

The thickness of No. XII declines rapidly towards Wilkes Barre. At the Red Ash colliery, which is 25 miles due north from the Nesquehoning R. R. tunnel, and immediately south of Wilkes Barre, the conglomerate measures but 97 feet. This change in the thickness of the conglomerate is as great in other directions, as shown by numerous sections made by the Geological Survey.

The variability in the thickness of the Productive Coal measures, and of their included coal beds, is relatively almost as great as that of the conglomerate; it would be impossible, to select any one section to illustrate the thickness, character, and succession of the coal beds and their included rocks throughout the region.

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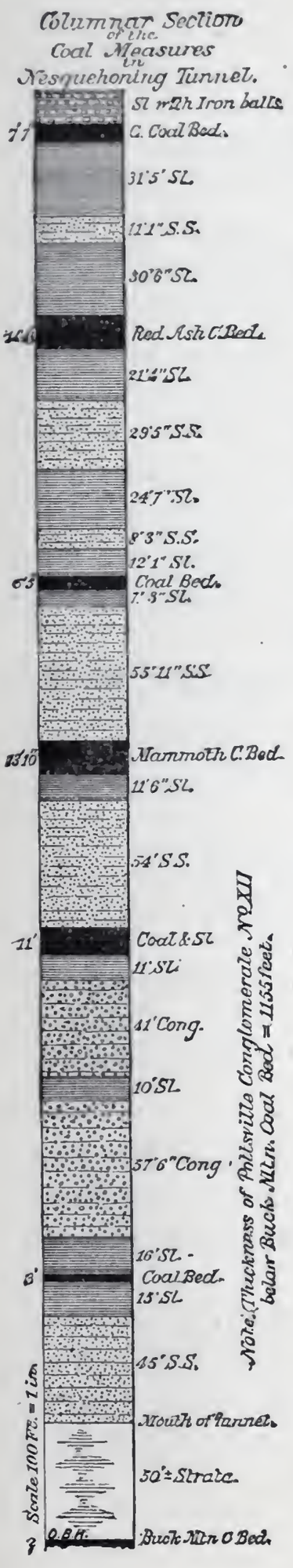
* The Rhume run tunnel back of the village of Nesquehoning is frequently called the Nesquehoning tunnel and was used solely for mining purposes; it must be distinguished from the Nesquehoning railroad tunnel through the Locust mountain, north of Lansford.

FIG. 3.



The non-parallelism of the anthracite beds, in many localities, is now proven beyond a question. In fact, it is doubtful whether the certain identification of any of the Carboniferous strata, over the entire coal region, can be accepted as at present determined, other than that of the Mammoth coal bed and the base of the Pottsville conglomerate No. XII. Until the relationship of the anthracite beds in the different districts is established, it is folly to attempt, as has often been done, to identify the anthracite coal measures with those in the Pennsylvania bituminous fields.

The accompanying section (Fig. 3), measured in the Nesquehoning or Rhume Run tunnel, is as representative of the anthracite measures as any which could probably be referred to. The Mammoth bed, which is 13 feet 10 inches thick in this section, changes, as do all the other coal beds, very much in thickness, in the number of separate benches of coal which it contains, and the amount of slate and poor coal which is included between the good coal benches or layers. Half a mile west of Summit Hill village, where the coal was first quarried in a surface cutting in 1792, the bed is about 50 feet thick; at one point, where a very careful measurement was made, the bed was composed of 21 separate benches of coal, having an aggregate thickness of 40 feet 3 inches, which were separated by 20 layers of slate, with a total thickness of 12 feet 10 inches. The average thickness of the bed east of Nesquehoning colliery is estimated to be 29 feet, with 23 feet of merchantable coal, and west of Rhume run to the Schuylkill-Carbon County line 55 feet, with only 27 feet of coal.

Between the county line and Tamaqua the average thickness of merchantable coal contained in the Mammoth bed is about 27 feet, and the average thickness of the coal bed itself is 43 feet. In Colliery No. 9 of the Lehigh Coal and Navigation Company, west of Summit Hill village, the Mammoth bed has an average thickness of 50 feet and contains on the average 25 feet of merchantable coal. At one point in the colliery, where the bed has evidently been subjected to a local squeeze, it measures 114 feet thick and contains 106 feet of coal; while a thickness of 60 or 70 feet for the bed, with 40 or 50 feet of good coal contained in it, is not unusual at many points in this mine.

The Red Ash bed, which is the bed most extensively worked in the Panther Creek valley next to the Mammoth, has an average thickness in the eastern and western ends of the basin of about 13 feet, containing 9 feet of coal, while in about one-third of the area of the basin near its centre the same bed has an average thickness of 9 feet with only 5 feet of coal.

In the Greenwood colliery workings, near Tamaqua, the following measurements were made:

Bed.	Average dip.	Coal bed.	Coal.	Per cent. of coal taken out of mines.
G.	57°	3 ft.	2 ft.	60
F.	57°	12 "	10 "	50
E.	51°	20 "	15 "	70
D.	57°	9 "	7 "	60
C.	57°	8 "	6 "	60
B.	57°	6 "	3 "	50
A.	55°	10 "	8 "	70

These facts, although local, are sufficient to show the great variability of the anthracite coal beds and the impossibility of reporting a section of any one bed, which shall be an average for any considerable portion of the region. In the First Report of Progress of the Anthracite Survey a number of sections are given, with a view of indicating, as near as possible, the average thickness of the coal measures, and the average thickness of the coal beds contained, in a number of localities. A summary of these sections is given in the following table:

Location of Sections.	Total Thickness of Coal Measures.	Total Thickness of Coal Beds.
Northern Field.		
Carbondale Basin, Forest City colliery . .	307′ 7″	19′ 6″
" " near Carbondale . . .	282′ 2″	13′
Lackawanna Basin, near Scranton . . .	633′	67′
Wilkes Barre Basin, near Wilkes Barre . .	867′ 3″	85′ 3″
Nanticoke Basin, near Nanticoke	918′	95′ 6″
Eastern Middle Field.		
Black Creek Basin, near Gowen	558′ 1″	38′ 1″
" " " near Ebervale	369′	36′
Hazleton Basin, Hazleton colliery . . .	528′ 1″	81′ 4″
Western Middle Field.		
Mahanoy Basin, Ellangowan colliery . .	767′	107′ 9″
Shamokin Basin, Trevorton Estate . . .	1408′	117′
Southern Field.		
Panther Creek Basin, near Tamaqua . . .	2168′	126′
Pottsville Basin, near Pottsville	3097′	154′

The thickness assigned to the coal beds does not represent the thickness of merchantable coal contained in the beds, but the thickness of the beds, including the layers of slate and bony coal contained between the benches of good coal.

COMPOSITION AND ORIGIN OF PENNSYLVANIA ANTHRACITE.

The analyses of anthracite coals, which have been reported up to within a few years, have been largely of small specimens collected in special parts of individual mines, and do not show, either the composition of the coal which can be commanded by the trade from the colliery, or the true chemical constitution of the coal in the bed, throughout the mine in which the individual specimens were obtained. The larger specimens which have been collected for fuel tests would seem to have been selected with too much discrimination; for, comparing them with more recent analyses which have been made privately and by the Geological Survey,

they cannot constitute a criterion for the classification of the coals which they represent.

Thirty coals were recently collected by the survey in different parts of the region and analyzed,* not so much to show the composition of the coal contained in the different beds, as the fuel constituents of the coals shipped to market. In collecting these specimens, it was thought desirable to test the value of the judgment of the coal trade in discriminating between different coals, and in consequence the specimens were obtained from mines which were regarded by most consumers as producing coals of equal value. The specimens were collected from 100 to 200 tons of coal, as it was ready to be shipped to market, the amount collected in each case for analysis ranging from 100 to 200 pounds. The bulk of each specimen was then reduced by the ordinary methods used in sampling mineral products for qualitative and quantitative tests. The analysis of each individual specimen is recorded in detail on page xxxiv of the First Report of Progress of the Anthracite Survey. For present purposes it is not important to refer to the results in detail. A table of averages is given below, which shows the mean character of the coals mined from the more important beds of the Northern Field, in the vicinity of Wilkes Barre, the Eastern Middle Field, in the vicinity of Hazleton, the Western Middle Field, in the vicinity of Shenandoah, and the Southern Field, in the Panther Creek basin. The maximum of fixed carbon obtained in any one specimen was 88.2 per cent. as against 90 to 93 per cent., as has frequently been reported by different authorities. The minimum of fixed carbon was 78 per cent. as against 83 or 84 per cent., which has been generally considered to be about the minimum.

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* All the analyses referred to were made by Mr. Andrew S. McCreath, chemist for the Second Geological Survey of Pennsylvania.

Composition of Pennsylvania Anthracite.

No. of specimens.	Name of coal bed.	Name of coal field.	Chemical analysis.*						Specific gravity.	Percentage of constituents of fuel.		
			Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.		Fixed carbon.	Volatile combustible matter.	Fuel ratio, C. V.H.—C.
3	Wharton	Eastern Middle	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
5	Mammoth	Eastern Middle	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
2	Primrose	Western Middle	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
5	Mammoth	Western Middle	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
2	Primrose? (F)†	Southern	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
2	Buck Mountain	Western Middle	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
1	Seven Foot	Western Middle	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
7	Mammoth	Southern	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
3	Mammoth	Northern	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00
	B Coal Bed ‡	Loyalsock	1.295	8.100	83.344	1.031	6.230	100	——	91.14	8.86	10.29

* These analyses are arranged in the order of the percentage of fixed carbon in the fuel constituents.

† Called Red Ash bed in the Panther Creek basin.

‡ This coal, according to the classification referred to below, would be called a semi-anthracite, on account of the percentages of volatile matter and fixed carbon contained. The percentage of volatile matter is not as great, however, as that contained in many of the coals from the Shamokin and Lykens Valley districts, with which the Loyalsock coal favorably compares. The Shamokin and Lykens Valley coals are called anthracites by the trade, and on this basis the trade must consider Loyalsock or Bernice coal an anthracite.

One of the most extensively discussed questions connected with the region, and one about which the most unsatisfactory conclusions have been arrived at, has been the composition and classification of Pennsylvania anthracites. The original division of our Pennsylvania coals into anthracite, semi-anthracite, semi-bituminous, and bituminous was one founded largely upon their geographical distribution, although the supposed basis was the chemical composition of the coals. These names, as they have been indelibly fixed upon coals produced from special sections or individual mines, will always to some extent be made use of by the coal trade; they have, however, no scientific value. An interesting discussion of this subject was contributed to the Transactions* of the American Institute of Mining Engineers, by Dr. Persifor Frazer, and was subsequently published in Report MM. of the Second Geological Survey of Pennsylvania. As a result, the following classification† is suggested:

Classes of Coals.	Ratio $\frac{C}{\text{Vol. H. C.}}$: 1.
Hard-dry anthracite, ...	from 99 : 1 to 12 : 1
Semi-anthracite, ...	from 12 : 1 to 8 : 1
Semi-bituminous, ...	from 8 : 1 to 5 : 1
Bituminous, ...	from 5 : 1 to 0 : 1

In arranging the coals under this classification, and others proposed, the accidental impurities, such as sulphur and earthy matter are disregarded in the analysis, and the fuel constituents alone considered. The fuel ratio of each coal, or the fixed carbon divided by the volatile hydro-carbon, is represented by the first term of the ratio expressed in the table. While this classification is probably the best which has been suggested for our Pennsylvania coals, and may be used provisionally as a scientific basis, the coals as at present graded by the coal trade could not be arranged under this or any other classification; and, I do not believe that we have sufficient data, at present at our command, to suggest a final arrangement, which might be considered a scientific rating of the coals, and which would be accepted by the coal miners, venders, and consumers.

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* Vol. VI, page 434.

† See Report AC, page 15.

The analyses given in the above table are of coals from all sizes (mixed) which are shipped from the different collieries. It is found in practice that after the coal is passed through the breaker and screened into different sizes for shipment, the purity of the different sizes, as regards fixed carbon and ash, is very different. This is indicated by the following analyses of specimens collected from the Hauto screen building of the Lehigh Coal and Navigation Company.

Kind of Coal.	Water.	Volatile Matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Color of Ash.
Egg, . . .	1.722	3.518	88.489	.609	5.662	100	Light cream.
Stove, . .	1.426	4.156	83.672	.572	10.174	100	Cream.
Chestnut, .	1.732	4.046	80.715	.841	12.666	100	"
Pea, . . .	1.700	3.894	79.045	.697	14.664	100	"
Buckwheat,	1.690	4.058	76.918	.714	16.620	100	"

These coals are separated into the different desired sizes according to the mesh of the screen over which they pass. The sizes noted in the above table passed over and through sieve meshes of the following dimensions:

	Inches.		Inches.
Broken or grate, ...	through 4	over	2.5
Egg, ...	" 2.5	"	1.75
Stove, ...	" 1.75	"	1.25
Chestnut, ...	" 1.25	"	.75
Pea, ...	" .75	"	.50
Buckwheat, ...	" .50	"	.25

In preparing the coal for market, pieces of what is known as *Bony coal* are picked out as worthless and thrown on the dirt bank. The lustre of this coal is dull and it has a cannelly appearance; much of it is believed to be as good a fuel coal as that which is shipped from the same colliery to market. In fact, analyses recently made of three specimens* of this bony coal, from a certain colliery, proved them to contain more fuel constituents than the coal which was sold to the trade. It has been suggested that the *good* bony coal be called "*Cannel Anthracite.*"

* See First Report of Progress, Anthracite Region, page 181.

The ashes of the anthracite coals have varying compositions. The following two analyses show the composition of the ash obtained from the red and white ash coals, which are mined, respectively, in the Panther Creek basin.

	Red Ash.	White Ash.
Silica,	47.190	48.250
Alumina,	32.522	36.177
Sesquioxide of iron,	4.710	3 290
Oxide of manganese,	trace.	trace.
Lime,	3.640	1.950
Magnesia,	.965	.921
Sulphuric acid,	.712=Sulphur, . . .285	.490=Sulphur, . .196
Phosphoric acid,	1.958=Phosphorus, .855	.923=Phospho's, .403
Titanic acid,	.990	.750
Undetermined alkalies, etc.,	7.313	7.249
	100.000	100.000

It would appear, as far as the investigation has proceeded in the anthracite region, that it is impossible to establish the geological relationship of the different coal beds from a study of the chemical analyses of the coals which they contain. From an attempt made in this direction,* it was found that greater variations, frequently, existed between the analyses of duplicate specimens than between those of specimens from different beds.

Origin.—The existence of anthracite beds in Pennsylvania has never been satisfactorily explained. Two common and popular explanations are offered: first, that they are coked bituminous beds, the heat which has driven off the volatile matter being derived from intrusive rocks; but as no intrusive rocks have ever been discovered in the vicinity of the anthracite region, this explanation fails; second, that the necessary heat for the coking process was produced during the original plication of the region. As an answer to this latter explanation, it is only necessary to refer to the Belgian coal field, where the coal measures are not only highly corrugated, even more so than in the anthracite region, but the coals are bituminous,† containing high percentages of volatile matter. In considering both of these views, Prof. Lesley says:

* See First Report of Progress of the Anthracite Region, page 184.

† The coals are reported, however, to contain less volatile matter, as greater depths are reached, in some cases becoming true anthracites.

"If anthracite coal be a coke, then it follows that it should have more ash than the coal from which it was made. This is not the case. It is difficult to find, after a careful search, a bituminous coal which runs so low in ash as the anthracite. And if 40 per cent. of hydro-carbons have been expelled to make anthracite, it should have 10 per cent. of ash to 6 in bituminous coal, which it certainly has not."

It is further suggested that the genesis of anthracite will probably be accounted for by an inquiry into the character of the original vegetation which went to form the coal beds.

While I do not think that we have all the data collected in the anthracite region necessary to solve this question, I believe we are in possession of sufficient facts to suggest its most probable solution. The change of the original vegetable deposit into anthracite has probably been effected to a great extent through a chemical process, by which a portion of the carbon has been oxidized, forming carbonic acid, at the expense of the combined oxygen, a portion of the combined hydrogen has been oxidized, forming water, and a portion of the carbon and hydrogen have been combined, forming marsh gas. The removal of the marsh gas (carburetted-hydrogen) in this way, as pointed out by Bischof, may convert bituminous coal into anthracite. Although heat would naturally aid this conversion, it might be the result of decomposition at ordinary temperature. The heat, which was unquestionably produced in the anthracite region during the plication of the strata, has possibly helped the process, and the water which was held by the strata in their semi-plastic condition at the time of their plication has probably been a potent aid. Daubrée has shown that a small amount of water raised to a temperature of between 300° and 400° C. will produce rock metamorphism.

The occurrence of an anthracite bed in the Loyalsock field, with a bituminous bed 60 feet vertically below it, where the strata are not plicated, but where they have all the structural peculiarities of the nearly horizontal strata in the Pennsylvania bituminous field, would seem to throw some light on this much vexed question, and lend support to the explanation here proposed.

The question has been asked, why should the coal beds of the anthracite basins be more oxidized than those of the bituminous fields. In reply, Prof. Lesley suggests this answer: "The undisturbed western coal measures consist largely of clay strata; those of the eastern coal measures consist in a much larger proportion of sand and gravel. This would favor the superior oxidation of the latter." Another important consideration is the fact that the circumstances, subsequent to and during the time in which the vegetable matter which composed the anthracite beds was accumulated, were probably more favorable to this oxidation. While the plication of the anthracite region would not seem to alone satisfactorily account for the origin of the anthracitic character of the coals, yet the time and circumstances under which it took place were probably more favorable to its formation than in the Belgian field. Many ideas connected with this suggested explanation have been thrown out by a number of noted English and American authorities, whom the author hopes to cite in a discussion of this subject to be published in the future, and who are not noted in this brief reference.

MINING.

The general methods of opening the anthracite mines are various, depending largely upon the mode of occurrence of the coal bed. The early mines were mostly excavated out of the coal beds above water-level, in order to obtain natural drainage. This was accomplished, (1), by quarrying the coal at a natural outcrop, as at the old Summit Hill mines, and as is being done at present in the vicinity of Hazleton; (2), by water-level drifts, driven along the strike of the bed; (3), by water-level tunnels driven across the coal beds perpendicular to the strike [the drift and tunnel plans are illustrated by many of the abandoned mines, and those which are still being worked in Schuylkill and south-western Carbon Counties]; (4), by slopes driven down the dip of the bed; and (5), by vertical shafts.

Between the lowest point of outlet to the mine and the outcrop of the coal bed, the coal is worked from nearly horizontal gangways driven along the strike of the bed; the coal between any two gangways being worked out from the lower one, by the ordinary pillar

and breast system. In high dipping beds the lift, or distance along the dip of. the bed between any two gangways, varies from 75 to 100 yards. In beds with low dips the positions of the gangways are dependent upon local conditions. The size of the gangways, pillars, and breasts or chambers varies according to circumstances.

There are many modifications in the details of the pillar and breast system, that most generally employed in the region, which are to some extent dependent upon the choice of the mine superintendent, but more generally are governed by the lay of the coal bed, its thickness, and the constitution and character of the enclosing rocks.

The percentage of the amount of coal which is originally contained in the ground before mining is commenced, which is left in as pillars for roof support, and the percentage which is taken out, is variable. In the high dipping beds of the Panther Creek basin, between Tamaqua and Mauch Chunk, the percentage of coal which has been taken out of the individual mines, from their original opening to the present time, varies between 51 and 69 per cent.; while for the entire basin, between the years 1820 and 1883, the amount of coal removed was 59 per cent., and that left in the pillars and other portions of the mines was 41 per cent. of the original contents.

The better and more economical methods of mining which have been introduced into this basin during the past few years have resulted in taking out of the mines, for the years 1881 and 1882, 70 per cent. of the original coal contained. In other portions of the region, notably in limited sections of the Northern Coal Field, where the beds do not dip as steeply as in the Southern Field, and where the conditions for more economical mining generally obtain, as much as 80 or even 85 per cent. of the coal originally contained is taken out of the mines.

This percentage does not represent the amount which is converted into commercial fuel, since the coal has to be broken into market sizes and has to be freed from the slate and bad coal which is mixed with the good coal when sent from the mine to the breaker. This preparation of coal for market is attended with great waste. In the Panther Creek region, between the years 1820 and 1883, 32 per cent. of the coal originally contained

in the worked areas was sent directly from the mines and breakers to the dirt banks as waste, and only 27 per cent. was converted into fuel coal. During the years 1881 and 1882 the waste coal only amounted to 24 per cent. of the original contents, and as much as 46 per cent. was converted into fuel coal. This shows that from 1820 to 1883 of the 59 per cent. of the original contents of the coal beds which was taken out of the mines, more than half (56 per cent.) was thrown on the waste heap, while a little less than half was converted into fuel. During the years 1881 and 1882, of the 70 per cent. of the original contents taken out of the mines, only one-third (34 per cent.) was thrown on the waste heap and two-thirds were converted into fuel. This gain is due to two causes: first, to mechanical improvements and greater economy in breaking the coal; and, second, to the present consumption of the smaller sizes of coal which were formerly thrown away on the dirt bank.

The waste in the preparation of coal is due to breaking, to screening, and to attrition while the coal is passing from the shutes to the pockets and market cars. This waste is dependent upon so many varying conditions connected not only with the construction and working of the breaker, but upon the character of individual coals, that it is impossible to give an average for the region. In the Shenandoah district the waste in breaking and preparing the Mammoth coal at a number of colleries was found to be 15 per cent. In the vicinity of Wilkes Barre, in preparing coal from the Red Ash bed at several colleries, but 6 per cent. of waste was obtained, while in preparing coal from the Baltimore or Mammoth bed about 11 per cent. of waste resulted. In the Shamokin district the waste from breaking and screening is reported in some cases to be as high as 25 and 30 per cent.

The utilization of the waste coal which is now thrown on the dirt or culm bank is a question of great economical importance to this region. Several methods have been suggested for preparing the fine coal and manufacturing it into blocks of various sizes, none of which have yet come into general use. While it would seem to be practical, to manufacture such fuel under particularly favorable conditions, I believe that the final solution of the problem is not the manufacture of the waste coal into forms

which would make it a possible fuel, with the same conditions of combustion under which the various sizes of broken anthracite are used, but rather to manufacture a special form of grate and furnace where the waste coal can be consumed in its present form. Of course, where the culm is filled with poor coal and slate, this must be removed in order to obtain the best results. In other words; the design of the furnaces must be adapted to the existing form of the coal, and not the form of the coal adapted to the existing forms of furnaces. I believe the most practical results in making use of waste coal, have been obtained by Mr. J. E. Wootten, General Manager of the Philadelphia and Reading Railroad, who has designed a special form of grate and furnace for its consumption in its natural condition.

STATISTICS OF PRODUCTION.

The economical importance of the anthracite coal fields can be better realized from an inspection of some of the statistics connected with their production, rather than from a study of the brief description, which has been here attempted, of their natural characteristics. During the year 1883 the estimated shipment of bituminous coal in Pennsylvania was 24,000,000 tons, and of bituminous coal in all the other States about 40,000,000 tons, while the reported shipment of Pennsylvania anthracite was 31,793,027 tons.* The shipment of anthracite was 79 per cent. of the total coal shipment in all the other States, and 33 per cent. of the total shipment of the United States, including both Pennsylvania bituminous and anthracite coal. During the same year the estimated production of fuel-coal throughout the World was 385,000,000 tons, of which, it is perceived, the shipment of the anthracite region was 8 per cent. During the year 1883, according to the Mine Inspectors' Reports, there were 386 mines in operation in the region, producing in the aggregate 33,955,831† tons. In a number of instances the coal from several mines is prepared at the same breaker and mixed, prior to shipment; so that, according to the report of Mr. John H. Jones, accountant for the transportation companies, there were only 357 shipping collieries. In 1883 the largest

* Includes Loyalsock shipment (80,124 tons). Ton equals 2,240 pounds.

† Includes Loyalsock production (84,376 tons).

producing colliery was Breaker No. 2 of the Susquehanna Coal Company, in the vicinity of Nanticoke, its total production for the year being 420,543.7 tons.

The division of the field by the coal trade into regions and districts, with the amount of coal produced in each district, is given in the following table:

Wyoming Region.

Name of District.	Number of producing Mines.	Production.
Loyalsock,	1	84,376.00
Carbondale,	21	1,728,858.00
Scranton,	40	4,725,315.00
Pittston,	39	2,173,144.50
Wilkes Barre, Plymouth,	59	7,400,095.80
Totals,	160	16,111,789.30

Lehigh Region.

Green Mountain,	5	429,555.30
Black Creek,	24	2,455,091.65
Hazleton,	15	1,443,448.00
Beaver Meadow,	12	1,236,005.60
Totals,	56	5,564,100.55

Schuylkill Region.

East Mahanoy,	17	1,432,837.45
West Mahanoy,	56	5,174,693.55
Shamokin,	21	1,439,367.35
Panther Creek,	12	825,185.70
East Schuylkill,	24	331,569.35
West Schuylkill,	30	428,310.55
Lorberry,	4	167,191.35
Lykens Valley,	6	1,266,912.70
Totals,	170	11,066,268.00
Grand Totals,	386	32,742,157.85*

* This is less than the total production (33,955,831 tons) obtained from the Mine Inspectors' reports. In the case of some of the individual mines, it has been impossible to discriminate between the shipment and the production.

The difference between the production as given by the Mine Inspectors and the shipment as given by Mr. Jones, is 2,162,804 tons, which represents the amount of coal consumed at and in the vicinity of the collieries.

The coals which are shipped from these different districts have been generally divided by the coal trade into eight classes, as follows:

(1) Hard white-ash coal, that shipped from all the collieries (53) in the Lehigh region, from 14 collieries in the East Mahanoy district, from 34 collieries in the West Mahanoy district, from 9 collieries in the Panther Creek district, and from 6 collieries in the East Schuylkill district.

(2) Free-burning white ash, that shipped from the Loyalsock basin, from all the collieries in the Carbondale (26) and Scranton (41) districts, from 27 collieries in the Pittston district, from 30 collieries in the Wilkes Barre district, from 15 collieries in the Plymouth district, from 1 colliery in the East Mahanoy district, from 21 collieries in the West Mahanoy district, from 8 collieries in the East Schuylkill district, and from 17 collieries in the West Schuylkill district.

(3) Schuylkill red ash, that shipped from 1 colliery in the West Mahanoy district, from 1 colliery in the Panther Creek district, from 5 collieries in the East Schuylkill district, and from 3 collieries in the West Schuylkill district.

(4) Shamokin, that shipped from 19 collieries in the Shamokin district.

(5) Lorberry red ash, that shipped from all the collieries (4) in the Lorberry district.

(6) Lykens Valley red ash, that shipped from all the collieries (6) in the Lykens Valley district.

(7) Trevorton, that shipped from 2 collieries in the Shamokin district.

(8) Wyoming red ash, that shipped from 1 colliery in the Pittston district, from 6 collieries in the Wilkes Barre district, and from 7 collieries in the Plymouth district.

Of the total coal shipped 49.08 per cent. was sent from the Wyoming region, 19.23 per cent. from the Lehigh region, and 31.69 per cent. from the Schuylkill region. This coal is now carried

to market by seven large transporting companies, as given in the following table, with the number of tons carried by each company.

INTEREST.	TONS, 1882.	TONS, 1883.
Philadelphia and Reading Railroad, .	7,000,113	10,487,003
Lehigh Valley Railroad, . . .	5,933,740	6,271,773
Central Railroad of New Jersey, . .	4,211,052	*1,745,399
Delaware, Lackawanna and Western Railroad,	4,638,717	5,079,123
Delaware and Hudson Canal Company,	3,203,168	3,512,971
Pennsylvania Railroad Company, .	2,332,974	2,773,419
Pennsylvania Coal Company, . .	1,469,821	1,541,145
New York, Lake Erie and Western R. R.,	330,511	382,194
Totals, ...	29,120,096	31,793,027

Of the total shipment from the region, 13,148,185 tons were sent to the Eastern competitive points at tide water, the remaining portion being sold to the line trade. This large percentage (41), of the total shipment, sent to the above points makes it necessary for the coal transportation companies to regulate the production of the region through a board of control, in order to restrict the production within the limits of the demand, and to make it possible to mine and transport coal without direct loss either to the miners or railroads. In the year 1883 the production was restricted by the mining being stopped during 60 days, scattered through the year.

The details of the distribution for 1882 are shown in the following table:

To Pennsylvania, New York and New Jersey, . .	19,957,789
To the New England States, ...	5,064,775
To the Western States, ...	2,213,107
To the Southern States, including Delaware, Maryland and the District of Columbia, . .	1,168,730
To the Pacific Coast, ...	49,065
To the Dominion of Canada, ...	616,875
To Foreign ports, ...	49,735
Total, gross tons, ...	29,120,076

* Is for five months only; after June 1st the tonnage was figured in with that of the Philadelphia and Reading Railroad as lessee.

The largest mining company is the Philadelphia and Reading Coal and Iron Company, which is operated in conjunction with the Philadelphia and Reading Railroad Company. The production of this company during 1883 was 4,582,667 tons. The collieries leased by the company during the same year produced 1,491,465 tons, making an aggregate of 6,074,132 tons. The cost to this company per ton for mining in 1883 was $\$1.49\frac{5}{10}$.

The total shipment of coal from the anthracite region, reported by Mr. P. W. Sheafer up to 1868 and by Mr. John H. Jones since then and up to the end of 1881, was 438,580,394 tons. It is estimated that the total production at the mines during the same period was 478,052,629 tons. If to this be added the production of the mines, as reported by the Mine Inspectors, for the years 1882 and 1883, the total production of the region from the commencement of mining up to 1884 would be 543,205,150 tons.

It is difficult to realize this tonnage. Estimating that, on an average, a ton of coal (2,240 pounds) in the bed contains 25 cubic feet, this tonnage would form a solid wall 100 feet wide and 100 feet high for a distance of 257 miles; or it would form a solid wall along the line of the P. & R. R. R. between Philadelphia and New York 100 feet wide and over 286 feet high. If a similar estimate be made of the coal in broken sizes, as it is shipped to market, on a basis of 40 cubic feet to the ton, it would form a wall 100 feet wide and 100 high for 411 miles, or along the railroad between the two cities above referred to, 100 feet wide and over 458 feet high.

During the year the estimated value at the mines of a ton of anthracite was $2.10; so that the aggregate spot value of the anthracite coal produced during that year in Pennsylvania would be $71,307,245. The spot value of the bituminous coals, at all the mines in the United States during the same year, on the basis of $1.20 per ton, would be $76,800,000, while, according to Mr. Albert Williams, in charge of the mining statistics of the United States Geological Survey, the total value of the gold and silver mined during the same year in the United States was $76,200,000.*

As to the exhaustion of special parts of the coal fields or of the

* From estimates of the Director of the Mint: Gold = $30,000,000 and Silver = $46,200,000; total = $76,200,000.

entire region, nothing can be added to my reference to the subject in the First Report of Progress, Anthracite Region,* as follows:

"The Survey has at present no data upon which to base any conclusion which would be of practical value. I have never made an estimate as to the duration of the Anthracite Coal Fields, because the Geological Survey has not advanced sufficiently to enable me to do so. In fact, the Panther Creek basin, which covers about one-fortieth of the entire area of the field, is the only locality where any measurements have been completed by the Survey as to the amount of coal taken out, or that which still remains to be mined."

"Mr. P. W. Sheafer, who has probably given the subject more careful consideration than any one else, has named something less than two hundred years as the time when the Anthracite Fields will be practically worked out. Mr. Sheafer has made a general statement that the field originally contained about 25,000,000,000 tons of coal. Up to January 1st, 1883, I have estimated that the total production amounted to 509,333,695 tons. It has been generally thought that but one-third of the coal contained in the area which has thus far been mined over in the entire region, has been consumed as fuel, so that up to last January an area has been exhausted which originally contained about 1,500,000,000 tons, 23,500,000,000 tons remaining untouched. If this same proportion of production to original contents be applied to that which still remains, about 8,000,000,000 tons would represent the possible future production."

"According to the Mine Inspectors' report, there was produced last year (1882) 31,281,066 tons. If this production should remain constant for all future time, the field would be exhausted in a little over two hundred years."

"Such a conclusion is quite untenable, for our yearly production is rapidly increasing. In 1870 there was shipped from the region 16,192,181 tons, and in 1880, 23,437,242 tons. The abrupt exhaustion of the coal fields is a practical impossibility, nor is it reasonable to suppose that, if, on an average, for every ton of coal won there are two lost, this will be the practice in future mining."

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SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

PROCEEDINGS
OF THE
ENGINEERS' CLUB OF PHILADELPHIA.
ORGANIZED DECEMBER 17th, 1877.

NOTE.—The Club, as a body, is not responsible for the facts and opinions advanced in its publications.

Vol. IV.] NOVEMBER, 1884. [No. 4.

XIV.

THE BROWN HEMATITE (LIMONITE) ORES OF THE SILURO-CAMBRIAN LIMESTONE, NO II, OF CENTRE CO., PA.

By E. V. D'INVILLIERS, Member of the Club.

Read June 7th, 1884.

WHILE professionally engaged in Centre County during the season of 1883, I was enabled to collect some data concerning the manner of occurrence and characteristics of the limonite iron ores of the Nittany and other limestone valleys of Centre County.

It may not be generally known that these limestone valleys in Central Pennsylvania are of *anticlinal* structure while the enclosing mountains are the *synclinals*, made up of the sand rocks of No. IV, Oneida and Medina, with a supporting base of No. III, Hudson River Slate, intervening between them and the limestones.

Thus by reason of the greater erosion of the limestone, the former highland of the anticlinal arches has become subordinate to sandstone basins, now making up the mountain ridges.

This erosion of the limestone has been both aërial and subaërial, and has consequently exerted a potent influence on the topography of the county as well as on its economical features,

changing the position of many of the ore deposits, while totally obliterating others.

The effects of such action are never entirely lost, for geological periods or epochs are all cumulative. But in confining ourselves to the region under discussion, erosion will certainly explain many of the interruptions in the different ore horizons. Add to this the fact that these anticlinal flexures are by no means straight lines, but vary in a vertical as well as in a horizontal plane along the trend of the axis, and a further feature of economical interest will be brought out.

For if it be admitted, that certain horizons in this limestone formation of more than 6,000 feet, are more ferriferous than others, any rise or fall in the axis will directly influence their position, alternately lifting the ferriferous beds to daylight and exposing them to atmospheric erosion, or burying them beneath higher non-ferriferous layers.

Of the origin of these hematite ores, opinion varies greatly. Much has been written, much suggested; and it would be useless for me in this short article to discuss the numerous theories extant. None of them seemed to be applicable to every case, a fact, it may be advanced, to be expected from the essential difference in the ores and their consequent different genesis. But men who have given much time and thought to the study of these deposits, assert, that whatever their origin, it was the same for all the limestone hematites, which have been subsequently altered to their present condition.

Be that as it may, the mines of Centre County show two distinct varieties of ore, while a third or *transition variety* may also be said to exist. Of these varieties the first is the

1. *Wash and lump hematite of the "Barrens."* The "Barrens" is a name given to those districts of the valley where sandy measures prevail, the result of disintegration on a large scale of the sandy magnesian beds low down in the series of No. II. Such districts were formerly left uncultivated on account of the comparative harshness of the soil, and as being usually devoid of water; but to-day, owing to the introduction of improved fertilizers and artesian wells, the name has become a mere figure of speech, and as far as ore-producing territory is concerned, it is certainly a misnomer.

These sand rocks were long considered to be the representatives of the underlying Potsdam sandstone formation; but the testimony of deep wells at many of the ore banks has proved conclusively that at least several hundred feet of limestone exist under the lowest of these sand rocks, while no boring has been deep enough to determine the total thickness of limestone measures down to the top layers of No. 1.

Where brought to daylight in the eastern and western end of Nittany Valley they are certainly 5,000 feet and probably more below the bottom of the overlying Hudson River Slates, and being everywhere largely ferriferous, their identification becomes a matter of economical importance. And this is not difficult; for in the leaching process they have undergone, these loosely aggregated rocks have fallen into sand, and it is probable that this same leaching action has concentrated their iron salts, which have been deposited as insoluble peroxide. What changes may have followed this process of deposition to bring about the irregular and confused appearance of the banks to-day, and the grading of the ore body downward from fine to coarse lumps, is a matter of speculation still. They all show evidence of being secondary or wash deposits, caught in vast caverns, of irregular shape, showing mixed sand, tough clay and rolled ore and flint balls. In the chief mines of the western barrens—notably at the Scotia Banks of Messrs. Carnegie and the Tow Hill Banks of the Juniata Mining Co.—after a superficial covering of 15 to 30 feet of mixed clay, fine ore and sand, the under surface reveals rock ore in large lumps mixed with clay in a confused arrangement.

The clay of these lower ores frequently occurs in non-ferruginous bands or dykes, running through the length of the bank, barren and hard to pass through the washers, but by no means cutting off the ore. It is usually a white to pink color.

The ore of the "Barrens" always needs jigging, in addition to washing, to free it from the mixed sand and flint accompanying it.

An analysis of these ores shows a remarkable absence of bisulphide of iron, at once suggesting a different genesis or chain of effects from the pipe ores to be immediately described, where this salt of iron is frequently present. The ore of these banks varies from a dark colored, often black hematite, with a pitch-

like lustre, rich in iron, to a lighter, liver-colored, compact hematite, not so rich.

These are indiscriminately mixed, with no tendency in either to the formation of a bed, apparently occupying irregular shaped estuaries scooped out of limestone, having their rich and lean spots.

I can imagine a theory to hold good here, by which soluble iron salts have been originally caught in porous sandstone layers interstratified with the limestones, and afterwards oxidized during which operation water slowly dissolved the whole formation, throwing the silicious members down as loose sand and filling the limestone crevices with hematite.

The record of each shaft in different parts of these deposits is different, varying from almost total barrenness to a good rich wash deposit 80′ + deep within a few yards of the lean spots. The larger banks of the region use a steam excavator, and so far as these wash deposits are concerned, they give very economical results. It is claimed that they do the work of forty men, requiring about ten men to operate. To be worked advantageously this machine requires a clean face of ore, free from rocky boulders or limestone ledges and about 15′ high.

Those used in Centre County excavate about 500 cubic yards of material per day of ten hours.

The system of working these banks has usually been to sink a series of trial shafts from 15 to 20′ deep in the direction the excavator is being worked, so as to gain some knowledge of the territory. The material excavated shows an average wash of about 1 in 5 or 7.

The composition of these lower ores is, of course, variable, but the following analyses of some of the more important banks, all made by Mr. A. S. McCreath from samples dried at 212° F., will serve to indicate their average character:

	1*	2	3	4	5	6	7
Iron,	42.550	49.200	52.750	52.950	45.375	52.575	48.250
Manganese,	.072	.208	.338	.403	.273	.079	.158
Sulphur,	.006	.026	.123	.094	.070	.006	.011
Phosphorus,	.113	.064	.086	.051	.051	.069	.109
Phos. in 100 pts. iron,	.265	.130	.163	.096	.112	.131	.226

* Hardly an average of this bank, which usually shows Fe. 45–47 per cent.; P. 0.80 per cent.

1. Juniata Mining Co., Tow Hill Mine.
2. Momson Cut.
3. Red Bank Cut.
4. Irwin Cut.
5. Screened wash ore.

} Scotia Banks, Carnegie Bros. & Co.

6. Ackley Bank. Idle at present.
7. Lytle Bank. "

Various analyses from small banks on the Juniata Co's. lands show from 45 to 52 per cent. iron and 0.05 to 0.10 per cent. phosphorus. R. H. Powell & Co. have been large consumers of this Tow Hill ore, and with it have established their reputation for foundry iron.

The excellent character of these ores, and the facility with which they are mined, has lead to the investment of considerable capital in their development; but there is still a great deal of virgin territory only awaiting the influence of local demand, through home furnaces, to return an abundant harvest to the operator.

The chief difficulties met with in the development of this region is the want of water for cleansing, necessitating the sinking of deep and expensive artesian wells and the removal of silicious matter, which, however, in the seven analyses presented, shows an average of 16.280 per cent. further reduced to 14.720 per cent. by throwing out No. 1, which does not represent the usual run of this mine.

2. Higher in these sandy measures occurs the *transition grade* of heavy hematite ores before referred to, displaying a character midway between those already described and the true limestone pipe ores. To this variety I would refer all the banks occurring from 3,500 to 5,000 feet below No. III slates, such as the Lambourn, Pond, Newell and Desert and others in the Buffalo Run country on the west, and that double row of mines on either side of the Sand Ridge on the east, where the rise of the anticlinal has brought up the uppermost of the sand layers, and which sinking eastward towards Clinton County, displays successively higher limestone beds with their characteristic pipe ores. This class of ores is usually amorphous and compact, liver-colored, and occurs in different sized pieces, though rarely as large as a man's fist.

The openings frequently show the characteristic feature of non-ferruginous clay bands of the "Barrens," though here it is much more calcareous.

In the *Pond Bank*, for example, where three open pits have been worked to a depth of 50 or 60 feet, a dyke of white clay 40′ wide extends northeast and southwest parallel to the trend of the rocks, apparently a decomposition from a slaty limestone *in sitû*, in which no ore can be found.

Above and below it, however, there is excellent ore territory, which in places has yielded a considerable amount of bomb shell ore, not usually noticeable in these valleys. Quite an admixture of a white feldspathic mineral, not unlike chalcedonic quartz, though more opaque, occupies small nests and streaks in this ore, a feature noticeable both in the Pond Bank and the Zimmerman and Darrah Banks in Marion Township on the east. These ores are nearly all cold short, though the local variations within short distances from cold short, through neutral to red short ores, is a remarkable feature of the Nittany Valley ores.

Many of these banks show noses of undecomposed siliceous magnesian limestones jutting out from the sides of the openings, which, however, do not cut off the ore.

A few analyses of this variety of ore will serve to show its varying characteristics, so I append the following made by Mr. McCreath from samples dried at 212° F.:

	1	2	3	4	5	6	7
Iron,	44.200	40.250	47.000	46.325	49.800	44.550	46.050
Manganese,	.273	.965	.309	.252	.386	.136	.504
Sulphur,	.023	.002	.002	.033	.040	.024	.027
Phosphorus,	.131	.365	.313	.199	.185	.115	.199
Phos. in 100 pts. iron,	.296	.906	.666	.410	.371	.258	.432

(1) Pond Bank, Buffalo Run, 7 miles S. W. of Bellefonte.

(2) Lambourn Bank, Milesburg Iron Works, 7 miles S. W. of Bellefonte.

(3) Desert Bank (Celtic Co.), near Geo. Mattern's.

(4) Love Bank (Dunkirk Mining Co.), Loveville.

(5) Darrah Bank (Milesburg Iron Works), 4 miles E. of Bellefonte.

(6) Streuble Bank, $\frac{2}{3}$ miles S. W. State Agricultural College.

(7) Johnson Bank (Brown, Diven & Co.), State Agricultural College.

The variation in the different constituents of these ores is very noticeable; but they occur throughout different horizons in about 1,500 feet limestone; have been exposed to many changes since their deposition and developed to different extents.

No average composition can be assigned to them, as each bank presents its own characteristics. The first two of them, the Pond and Lambourn Banks, occurring on opposite sides of the same anticlinal ridge, about one mile apart and in precisely similar rocks, show a variation in iron by analysis of from 44.200 per cent. to 40.250 per cent.; in manganese from .273 to .965, and in phosphorus from .131 in the former to .365 in the latter.

3. The third variety is the *pipe ore*, so called from its occurrence in slender cylindrical stems, whose sides are joined together forming masses several inches in circumference and frequently three or four feet long.

These ores occur at various horizons in the limestone, and though, as far as developed banks are concerned, usually *higher* in the series than either of the two varieties already described, it is by no means certain that some of them do not occur in the 1,000′ + of measures beneath them down to the top of the No. 1 Potsdam sandstone. In comparing these ore-bearing limestones with those of the Great Valley in Southeast Pennsylvania, it may be well to remark that neither of the two principal horizons which have furnished the bulk of material to the Lehigh and Schuylkill furnaces, is represented in Centre County. In that region the transition beds between the Potsdam sandstone and the Siluro-Cambrian limestones and between the limestones and Hudson River Slates, or in other words, the bottom and top of No. II form the chief ore-bearing rocks.

Of these, the first is no where brought to daylight in Centre County, being buried beneath 1,000′ + of rock along the floor of Nittany and Penn's Valleys.

The second or upper horizon has not been found to be ore bearing as yet, a fact which may be explained by the occurrence of 400′ + of Trenton fossiliferous limestone here, whereas its almost total absence in the Great Valley allows of the contact of

the slates with the ferriferous magnesian limestones. Again, the frequent connection of damourite slate beds with the chief ore bodies in the southeastern section of the State, is not observed in Centre County. It is true, that most of the pipe ores are accompanied with a white and buff colored clay, which may be the result of the decomposition of the slate bands; but it may also represent the disintegration of the magnesian limestones themselves.

While the chemical explanation of these facts is still a matter of speculation, repeated examinations of the ore banks in various parts of Nittany and Penn's Valleys leads me to believe that the pipe ore deposits are due either: 1. To the decomposition of iron pyrites, originally contained in the limestone or slate bands and after oxidation into a soluble sulphate, filled into crevices or channels eaten out of limestone by underground erosion, and changed there into peroxide; or, 2. To the prior production of ferrous carbonate, by reaction between ferrous sulphate and the calcium carbonate of the limestone, and eventual conversion into limonite by oxidation and hydration.

The manner of occurrence between walls of regularly bedded limestones, sometimes as thin shells or plates of ore and again as large pipes in masses 8 to 10 feet thick, would seem to confirm one or the other of these views, while the presence of iron pyrites in perfectly undecomposed pipes surrounded with thoroughly oxidized limonite in some of the banks lends even greater probability to this theory.

The presence of pyrite in hematite is not new, and the many analyses of these Centre County pipe ores all show the frequency of its occurrence here.

In those banks where a considerable surface deposit has been preserved in the general erosion of the region, oxidation has been so complete as to show but a low percentage of sulphur, whereas in the case of the Sinking Creek Mine and others, where mining is being carried on between limestone beds in the absence of surface deposits, the ore has not yet been thoroughly oxidized and shows cores of pyrite in all stages of metamorphism.

The outcropping of these pipe ores is spread out to a much greater extent than they occupy lower down between limestone walls, and the width of this outcrop is determined by the topo-

graphy of the country which has preserved it from being swept away.

This surface ore is greatly disintegrated, and indeed is so fine occasionally as to be with difficulty distinguished from so much reddish-brown earth or loam.

But a close inspection will reveal the presence of small stems or pipes. This material usually shows a percentage of 1 cubic yard (about 2 tons) for every 4 or 5 cubic yards of material washed.

My investigations in the field did not tend to confirm the popular belief in continuous belts of ore-producing territory through miles of surface outcrop. At best, while assigning approximate horizons in the limestones to these pipe ore deposits, they have their rich and lean places, feather out entirely in the line of their strike and widen again into masses several yards thick, while keeping a general parallelism of bedding with the parent rock and liable to show its changes of dip.

It is too early to speculate on the possibilities of these deposits in a field so partially opened up; but the ore has certainly been found to great depths and much original outcrop soil is still untouched. Many of the present operations exist on a wash derived from pipe ore beds, caught in gulleys or flats; but evidences are not wanting of the existence of pipe ore beds in places from which large amounts of ore have been taken.

Thus, in one of the old Valentine operations south of Bellefonte, a pipe ore bed averaging 6′ thick was drifted upon for a considerable distance into the hill, and the ore drawn out by mules right to the hearth of the old Logan Furnace. When the bed became lean, stoping was carried up between southeast dipping limestone beds to a shaft let down from the top of the hill 125′ above the drift, where a most excellent and extensive outcrop deposit still remains untouched. The Messrs. Curtin likewise have at various times carried on extensive mining by drifts and shafts at their Logan Banks, until compelled to abandon their operations by an excess of water. So likewise at the famous Pennsylvania Ore Banks, Snavely, Hecla, Sinking Creek and others, the occurrence of the ore between limestone beds can be well demonstrated.

Trial shafts at various banks have been carried down 50, 80 and even 100 feet in good wash material, showing the extent of surface disintegration where the circumstances have been such as to preserve it from erosion. But 30′ of wash is about a fair average. Like all hematite ore banks, the mines in Nittany Valley show the usual accompaniment of clay banks, "horses" of rock and mixed flint. But these ores show a remarkable evenness and are especially adapted for the various purposes of charcoal iron which hitherto has been the sole product in Centre County.

The reputation of Pennsylvania charcoal blooms was mainly made at the old Pennsylvania Furnace, from local ores mined from the bank of that name.

Ordinary care in the selection of suitable mixtures would qualify these ores for almost any use, though but few of them are low enough in phosphorus to fit them for Bessemer iron. A few analyses of the principal banks, made by Mr. McCreath from samples dried at 212° F., will furnish an idea of the character of these ores.

	1	2	3	4	5	6	7	8
Metallic iron, ...	50.200	46.550	54.123	50.825	45.725	53.075	46.250	52.550
Manganese, ...	.100	.252	.129	.144	.165	.180	.670	.187
Sulphur, ...	.054	.034	.470	.028	.022	.031	.040	.024
Phosphorus, ...	.140	.136	.098	.111	.185	.144	.124	.101
Phos. in 100 pts. iron, . .	.278	.292	.181	.216	.404	.271	.268	.191

1. Gatesburg Bank, Valentines & Co., 3 miles E., N. E. Bellefonte.

2. Watson Bank, Milesburg Iron Works, 2 miles S. W. Centre Hall, Penn's Valley.

3. Sinking Creek Mine, Penns Valley Mining Co., 1 mile E. Centre Hill, *lump ore.*

4. Nigh Bank, Valentines & Co., 3 miles S. E. Bellefonte.

5. Taylor Bank, " 3 miles E. Bellefonte.

6. Howard Furnace Bank, Lauth & Co., 1 mile W. of Hublersburg.

7. Hecla Bank, Milesburg Iron Works, $1\frac{1}{4}$ miles west of Hublersburg.

8. Washington Furnace Bank, 3 miles N. E. of Jacksonville.

These pipe ores have been mined with more or less interruption

all through the present century, but have only been "washed" during the past fifteen years.

At first only the large lumps were selected for furnace use, and immense screening floors still exist to mark this means of preparation.

The successful completion of the first artesian well at the Nigh Bank, 180′ deep, furnishing a copious supply of the purest water drawn from underground water-courses, led to complete revolution in mining methods and the erection of jigs and washers for the more thorough removal of flint and cleansing of the ores.

Some of these wells were carried down 400′ at great expense before striking water.

At the Beck Bank of the Howard Iron Co. the first well was sunk 600′ through limestone without finding water, though this failure may be attributed to the fact that the boring was conducted apparently through but a single stratum of limestone, which in this part of the valley is standing nearly vertical.

At all events a second attempt was more successful, with a record of 150′ through sandy measures and 82′ through limestone. 35′ of excellent surface wash ore has been proved and opened up here.

The barren wells at Loveville in the western part of the county are respectively 538′ (Haller & Co., Allegheny Steel Drill) and 1,102′ (Diamond Drill Co.) deep.

Mining in these pipe ore banks is carried on in a very primitive method, though improvements are to be desired rather in the method of opening up the property than in actual mining. It is doubtful whether the steam excavator can be advantageously used in these banks, for this machine, to be worked economically, requires a clean face of yielding material, free from the limestone ledges and "horses" of clay and sand so characteristic of these deposits. Attempts to utilize this machine by Messrs. Carnegie, in the old Pennsylvania Furnace Bank, and I believe, the Hostler Bank in Huntingdon Co., proved failures from these circumstances. The ore in these banks occurs in every conceivable form, whether in streaks of ore and clay, or in flattened scales, or bunched with sandstone, or in solid pipe masses: but everywhere showing a tendency to interstratification with the magnesian limestone beds.

Very few of the quartz and flint grains found with the pipe ores are water-worn or rounded, and so create a marked contrast with the state of affairs in the banks of the "Barrens" lower down in the measures. The slight difference in specific gravity between the ore and flint, and frequent occurrence of the former as flattened scales, made jigging very unremunerative, a circumstance likely to occur in any one of these pipe ore deposits.

To obviate this difficulty the screened ore was dropped on to flat platform cars about 8′ square, where the flint was separated by hand.

The mining plants consist usually of a double washer 25′ long, thus giving 50′ of traveling surface for cleansing the ores. The shafts are usually wooden, of hexagonal or octagonal shape, plated with iron and armed with iron teeth. They have a capacity of 20 to 50 tons per day of ten hours, according to the nature of the material used. They are run with a 30 to 40 horse-power engine, which is often made to do hoisting and pumping also. But two banks outside the large operations of Messrs. Carnegie and the Juniata Mining Co., in the "Barrens," use jigging machines. In both these cases the Bradford Jig is used.

The ore is carried to the washers by carts or sometimes by an incline plane, and costs from 90 cents to $1.25 per ton cleaned.

The Bellefonte Ore Co., operating about three miles east of Bellefonte, were placing washed and jigged ore in Bellefonte by teams for $2.10, including a royalty of 50 cents per ton, and as probably 35 cents of that went to haulage, it may be assumed that $1.25 will cover even the additional expense of jigging. The cost of mining the heavy brown hematites of the "Barrens" at Scotia and Juniata average about $1.50 per ton, *exclusive* of royalties.

This brief sketch may be fittingly closed by some few references to the present and future outlook of the iron trade in Centre County.

At present four charcoal furnaces, 32′ stack and 8′ bosh, comprise the entire converting agencies of the county. Pennsylvania Furnace, on the Huntingdon County line, has been recently changed to a coke furnace with 11′ bosh, 43′ high and 8′ at tunnel head, but as yet has made no record for itself. The

other four furnaces, all within short distances of Bellefonte, have a combined capacity of about 12,000 tons cold blast charcoal iron.

An idea of the work of these little charcoal furnaces may be gathered from various records of blast submitted to me by the proprietors, showing costs to vary from $18.00 to $25.00 per ton, with an average of about $22.50. The rapid denudation of the forest lands (the Valentine furnaces and forges requiring at least 100,000 tons of charcoal a year and a daily clearing of about an acre of land), presents an anxious feature to the future of this trade, while the replacement of charcoal metal with steel in many of the arts has also had its effect.

The want of railroad facilities for moving the ores has no doubt militated seriously against the erection of a good coke furnace at Bellefonte or Milesburg. But with the early completion of numerous graded and projected lines; with an abundance of 40 to 50 per cent. hematite ores readily and cheaply mined; limestone and coke more accessible than probably any other point in Central Pennsylvania, the locality certainly seems favorable for the manufacture of cheap iron, and the re-establishment of Centre County in the list of important iron producers.

In conclusion, I shall present an estimate made on September 22d, 1883, by Messrs. Coxe and Howe, President and Superintendent of the Montour Steel and Iron Co.; Robert and Abraham Valentine and General James A. Beaver, of Bellefonte, of cost per ton of coke metal at Bellefonte, supposing plant of 80 ton furnace with all modern improvements and mines owned by the company, and railroad communication with the ore banks established.

2¼ tons of ore (Nittany Valley hematites 45 to 50 per cent.) @ $1.50,	$3 38
1¼ tons coke @ $2.25,	2 81
Half ton limestone @ 50 cents,	25
Labor at furnace,	1 50
Miscellaneous, general repairs, etc.,	1 50
Sinking fund, for chilled furnace, breakage,	50
Interest at 6 per cent.,	35
Total,	$10 29

This still leaves a liberal margin for $12.00 iron.

It must be remembered that the above estimate is submitted only with a view to comparison with those so frequently published as representative of the capacity of various ore regions of the country. But any change in the method of estimating the cost of a ton of pig metal will affect all calculations alike, and it is quite probable that all such paper estimates fall from $1.00 to $3.00 below the actual working cost, everything being taken into consideration.

XV.

UTILIZING STEAM OF THE HIGHER PRESSURES.

By Horace See, Member of the Club.

Read June 21st, 1884.

Great strides, of late years, have been made on our steamships in the use of steam of the higher pressures. The high rates of speed, which sharp competition for the large transatlantic travel has brought about, where the burthen of the ship is almost entirely in the coal bunkers, and on long routes formerly monopolized by sailing vessels, make it important to study economy of fuel. The relation of some of the efforts with steam of the higher pressures in this direction, whether partially or wholly successful, are of sufficient value to merit our attention.

When the double expansion engine, using steam of 60 lbs. pressure per square inch, was introduced as an improvement upon the single expansion one, a marked economy followed the change. This was effected by dividing the work between two cylinders, part of the expansion of the steam being done in one, and then completed in the other, by which means the range of expansion and of temperature in each cylinder was limited.

Since then the working pressure has been steadily increasing, until to-day 110 lbs. of steam can be found on a number of our steamships. We have no data which shows any economy to have followed this rise, but, on the contrary, find it asserted in a paper read before the Institue of Naval Architects of England, that in

some vessels where this pressure is carried they are burning 2.6 lbs. of coal per horse power per hour. There is no doubt that some of this heavy consumption of coal must be charged to the manner in which it was burned, a part, however, is due to increasing the range of temperature in the cylinders.

Since the pressure has exceeded 80 lbs. the double expansion engine has relapsed in the condition of its old rival, and we must look elsewhere for a gain.

A few years ago the yacht "Anthracite" was built with the intention of reducing the coal consumption by using a very high pressure. For this purpose a water tube boiler was made for a working pressure of 500 lbs. The engine, classed as a triple expansion one was not properly such, two vertical cylinders only being used. One casting of different diameters contained both the high pressure and intermediate cylinder. The upper or smaller part was the high pressure, and received steam from the boiler during the first half of the down stroke; the lower or larger, the intermediate, received the steam during the up stroke, which did the work of the preceding down stroke in the high pressure cylinder. The space between the high pressure piston and the upper side of the intermediate piston was in connection with the receiver which supplied the low pressure cylinder.

The low pressure cylinder was double acting. The cylinders and their covers were heated by steam circulated through wrought iron pipes cast into the thickness of the metal. The reports of the trial of this vessel are very full. The extreme working pressure carried during any of the trials was 370 lbs. The consumption of coal per horse power per hour during Mr. Bramwell's trials is stated to have been 1.7 and 1.66, and during that of the Board of U. S. Engineers, 2.7. Mr. Bramwell attributes this increased consumption during the latter to be due to an inferior quality of coal, but more especially to the jackets being improperly worked.

Although we should look for a saving in coal from increase of pressure, it is also equally true that we cannot expect to find it there when the variation of temperature in any one cylinder is near 200°, as it was on the "Anthracite" during her most economical performance.

It is safe to say that the low initial pressure in the high pressure cylinder, as clearly shown by the accompanying indicator cards and diagram of pressures, is mostly due to the cooling influence of the walls of the cylinder upon the entering steam at the commencement of the stroke, and that steam of such high pressure could not be used economically in such a form of engine.

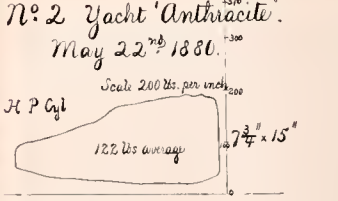
From the "S. S. Aberdeen," the boilers and machinery of which were built for steam of 125 lbs. working pressure, we have reports of great interest and value. The boilers are of the ordinary internally fired, fire tube type. The engine is of the triple expansion class, with three vertical cylinders, respectively 30, 45 and 70 inches in diameter by 54 inch stroke of piston, all separate and double acting. The high pressure cylinder is not jacketed, but the intermediate is with steam of 50 lbs., and the low pressure with 15 lbs. Mr. Kirk states that the consumption of coal upon the trial was 1.28 lbs. per indicated horse power per hour. He expects, according to the usual analogy, that the consumption of good Welsh coal at sea should be from 1.5 to 1.6 lbs. per indicated horse power. The moderate range of temperature in the cylinders is shown by the accompanying indicator cards, the variation in the high pressure being about 76°.

The internally fired boiler during this advance has shown that it could be built of large diameters and of sufficient strength to meet the requirements, consequently the necessity for the adoption of the water tube boiler, as a safe generator, has not as yet been felt.

The remarks of Mr. Kirk on steam jackets in his paper on the performance of the "Aberdeen" are worth repeating. He says: "I mentioned above that the high pressure cylinder was not jacketed, while the others were. As it did not seem to me that the value of jackets could be great on such an engine, with so limited a range of temperature in any one cylinder and a considerable speed of piston, I sacrificed steam jackets in the case of the high pressure cylinder, purely from prudential motives (the voyage being a very long one) to avoid any chance of cutting, when worked with very little lubrication, as it was desirable the engine should. Further, when we take into account the thickness of the interior chamber of the cylinder and the speed of

No 2 Yacht 'Anthracite'.

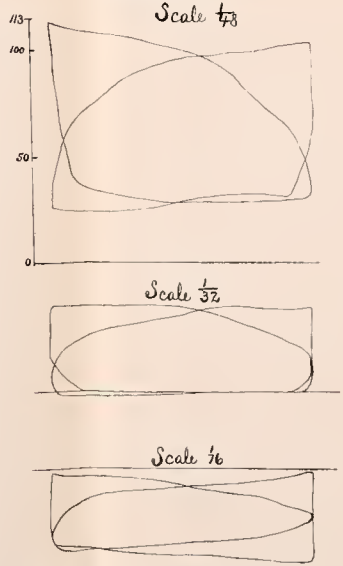
May 22nd 1880.



Steam - 370 lbs Chamber 9 lbs.

Vacuum 26⅜ Revolutions 132

S S 'Aberdeen'.



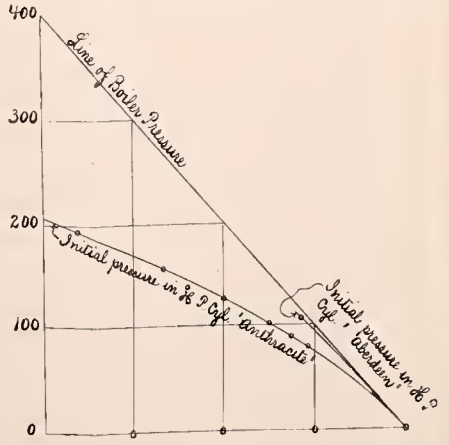
Steam - 113 Revol's - 65 4

Vacuum - 26½ IHP = 2086

Diagram showing Steam Pressures in Boilers and H.P. Cylinders

Trial Yacht "Anthracite", May 22nd 1880

" S.S. "Aberdeen", Feb. 1882



piston, it is not conceivable that the interior surface of the chamber can be maintained, by the steam on the outside of it, at a uniform temperature. In fact, the slower an engine runs the more efficient the jacket becomes.

"There is no doubt that in such an engine as the above, or, indeed, in any compound engine when the range of expansion and temperature is kept within moderate limits, that economy from the use of steam jackets is at least small; that, in fact, the steam condensed in the jackets, if admitted to the high pressure cylinder, would have been for all practical purposes as efficient.

"This has been a fortunate thing for the compound marine engine, as it is always extremely doubtful if at sea the steam jackets receive the attention they require to make them efficient.

"These remarks do not apply when engines are being worked at comparatively low powers!"

Mr. Parker stated during the discussion of Mr. Kirk's and his own paper: "With regard to jacketing, they experimented on the "Aberdeen," both with and without steam in the jackets, in the former case measuring the drain water. It was found that if the same weight of steam that was used in the jackets was utilized in the cylinders, the result would be practically the same."

As accidents, caused by the breakage of the cylinders from the unequal expansion of the inner and outer walls, are not uncommon when steam jacketing is employed, the expense of repairing the damage and the loss from the vessel being idle during repairs should be taken into account when considering the steam jacket as an economical adjunct.

It is not, therefore, only in the use of steam higher in pressure, or in such complications as steam jackets, that we must look for economy, but in the employment of an engine with a degree of efficiency proportionate to the increase of pressure, where the range of expansion and temperature in each cylinder during one stroke is limited by the division of the work between two or more cylinders.

XVI.

THE RESILIENCE OF STEEL.

By Wilfred Lewis, Member of the Club.

Read Jauuary 19th, 1884.

The problem of storing energy in a convenient shape for transportation or domestic use, suggests a wide range of possibilities, and opens up a large field for the exercise of inventive genius.

A good solution of the problem is urgently needed and as earnestly sought, but, as yet, all efforts seem to have failed to accomplish practical and economical results.

That continued labors in this direction will finally be rewarded by success, is certainly within bounds of possibility, but meanwhile it appears as though everything that will not work must be tried first, and that a vast amount of knowledge must still be gained, by sad experience and disappointment. The subject of this paper was suggested by a case in point, the proposition being to utilize the energy stored in a number of steel springs for the propulsion of street cars.

The question which naturally arose, was: how much energy can be stored in a given weight of steel?

The answer to this question was at first sought from the data given in standard works of reference, but these were found to be so meagre and indefinite, that the writer was led to make some experiments, to be described. Before going into particulars, however, it will be of interest to note some of the various ways in which energy can be stored, and the comparative position of steel among them.

This has been done by a writer in the "English Mechanic and World of Science," for Nov. 2d, 1883, who compares the methods of storing energy by means of steel springs, India rubber, compressed air, hot water, and electricity, and expresses the results in terms of the weight of material required to store one horse-power per hour.

Of steel, he says that fifty tons of watch-springs, all fresh wound up, would not supply one horse-power for one hour.

Five or six tons of India rubber, or about three hundred pounds of compressed air, including the weight of a steel case to contain it, would yield about the same result, and the weight required to store this energy by means of hot water or electricity, is said to be at present about the same as for compressed air, with the future probabilities in favor of the storage battery. He also goes on to show that the energy stored in the shape of horse flesh, will yield 2,000,000 ft. lbs. per hour for five hours. The weight of the horse being taken at 1,500 lbs., gives for the energy stored about 6,670 ft. lbs. per lb. of the animal, and as this is a more convenient form of comparison, we find for the previous examples, that 18 ft. lbs. can be stored in a pound of steel; 100 ft. lbs. in a pound of rubber; 6,600 ft. lbs. in a pound of air, including its steel case, and about the same in a pound of hot water or storage battery.

According to the same writer, the energy stored in the coal, water and boiler of a locomotive, will yield about 25,000 ft. lbs. per pound of all the materials used in storing.

From these statements it appears that steel has comparatively but little capacity as a reservoir of power, although, as is well known, it has long been used successfully and even preferably, for such light work as the running of clocks and toys, where convenience and availability are the main points in view. If the figures just given were accepted as correct, it would seem hardly credible that any one would attempt the task of propelling a street car, upon the basis of 18 ft. lbs. per pound of material used for driving, but upon investigation it was found that considerable work had already been done upon an experimental car, for the purpose of having a practical test.

The invention is described in "The New York Scientific Times and Mercantile Register," for December 15th, 1883, as a "wonderful system, by which horses on street car lines will be abolished."

The working parts will be of phosphor-bronze, polished, and there will be 80 steel springs, each 3 inches wide, by $\frac{3}{32}$ inches thick, and 60 feet long, which, it is said, can be wound in two minutes, by a stationary engine at the depot.

This may be very quick work, but what is more to the point, the figures are given to show that by the use of this system, the

car companies can carry passengers for three cents, and make as much money as they now do at the present rates.

In the case of the springs running down before reaching the station, a wise provision has been made by the introduction of a "powerful hand-winding arrangement, so that the engineer can apply the arrangement while the car is in motion, and thus reach the station without delay," but, unfortunately, no provision appears to have been made for winding up the engineer.

"The car is also provided with an ice attachment for winter use, a governor to regulate the speed, and about sixteen hand-levers, for various clutches, all conveniently and easily handled."

Upon inquiry it was not surprising to find, that although considerable work had been done upon the polished bronze portion of the car, no experiments had yet been made to determine the duty of the steel springs in question; and having become interested in this part of the subject, as a matter of scientific importance, I undertook the following investigation to determine the possible resilience of steel:

The elasticity of a steel bar may be developed by extension, compression, torsion or flexure, the latter being a combination of the two former.

All steel springs are brought into action by torsion or flexure, not because any more work can be stored by these methods, for in reality there must be less than by either extension or compression, but because the forces involved are more manageable.

In flexure and torsion, the metal is strained in proportion to its distance from the neutral axis of the section, and therefore, the full amount of elasticity is developed only in the extreme fibres, but in direct tension or compression every particle of metal must yield its full share of duty.

It is impossible to determine what this may be under the most favorable conditions, because it may never be known when those conditions are reached. Everything, of course, depends upon the quality of the steel, and its physical treatment. No satisfactory data upon these points could be found; the effect of hardening was said to increase the elastic limit and ultimate strength, and to diminish the elongation and reduction of area, but the effect upon the modulus of elasticity was not given in connection with these other changes.

This modulus is given by Rankine, at 29,000,000 for soft steel, having a tenacity of 90,000 lbs., and a working strength of 30,000 lbs., and at 42,000,000 for hard steel, having a tenacity of 132,000 lbs., and a working strength of 44,000 lbs.

We have also, upon his authority, that within the elastic limit, the modulus for compression is sensibly equal to the modulus for extension.

Prof. Burr, in his work on the "Elasticity and Resistance of the Materials of Engineering," gives a table showing the effect of tempering upon the elastic limit and ultimate resistance, and the highest values there given for the elastic limit, are 58,350 lbs. before tempering, and 107,650 lbs. after tempering. The ultimate strength corresponding, is 110,340 lbs. before, and 169,430 lbs. after tempering.

These results were obtained from a mild grade of French steel, and, although this elastic limit is probably above that of average steel, it is of course below what might be expected of higher grades.

Assuming Rankine's figures for hard, untempered steel, we find that its resilience is 7 ft. lbs. per lb., under direct tension. That is to say, any given quantity of untempered steel is just capable of storing enough energy to raise its own weight, through a distance of 7 ft., and that a car without weight driven by such a spring, without any loss through friction, could not quite manage to ascend a hill eight feet high, without the assistance of the engineer.

Supposing the elastic limit to be 107,650, instead of 44,000, as given by Rankine, we have about 43 ft. lbs. per lb., a much better result, but still insignificant in comparison with horseflesh, or compressed air.

According to Rankine's formulæ for spiral steel springs, the torsional resilience of steel is greater for the same intensity of stress than that of direct tension or compression. This is due to the lower modulus of elasticity for torsion, which prevails against the loss from incomplete straining of the fibres. The modulus for shearing is given at 12,000,000, and assuming 44,000 for an elastic limit, we have 12 ft. lbs. per lb. of metal for the torsional resilience of steel springs.

In order to put these calculations to a practical test, I procured two door-springs, of $\frac{3}{16}$ inch wire, and about $3\frac{1}{2}$ feet long. One end was held in a vise, and, upon a lever attached to the free end, weights were suspended until a deflection of 180° was produced. The first specimen, which was $37\frac{1}{2}$ inches long, deflected 90° with a weight of 4 lbs., at 15 inches rad., without taking set, and 180° with 8 lbs., at $11\frac{1}{4}$ rad., showing a set of about 30°. The second specimen gave better results. It was $40\frac{1}{2}$ inches long, between clamps, and deflected 90° with a weight of 4 lbs., at 13 inches rad , and 180° with a weight of 8 lbs., at the same rad., showing not more than 5° set. Taking the latter case, we find the greatest shearing stress to have been 80,000 lbs. per square inch, and the resilience about 43 ft. lbs. per lb. Substituting these results in the general formula for torsional deflection, we find the modulus in this case to have been about 10,000,000, which corresponds closely with the values generally given.

Dividing the general formula for torsional resilience

$$R = \frac{\pi}{16}\frac{f^2 d^2 l}{C} \text{ by the weight } W = \frac{.28\,\pi\, d^2 l}{4}$$

and reducing to ft. lbs., letting f = intensity of stress, and C = modulus of elasticity for distortion, we have, for the energy developed per lb. of steel,

$$E = \frac{.075\, f^2}{C}$$

The ultimate value of E, from these experiments is, therefore, about 48 ft. lbs., allowing 80,000 lbs. for f and 10,000,000 for C. If the spring is strained to but half its elastic limit, but $\frac{1}{4}$ of this amount, or 12 ft. lbs. per lb., can be obtained, the same as deduced from Rankine's formula for the safe load.

In order to test still further the resilience of spring steel, I procured two clock springs wound in spiral forms. The first, which was $\frac{3}{8}$ inches wide, and .014 inches thick, weighed 605 grs., and was consequently 60 inches in length.

It was mounted upon a mandril and tested for each revolution in winding and unwinding, by a weight sliding upon an arm attached to the mandril. By this means the friction of the coils in pressing against each other could be measured, as well as any set which might occur. At twelve revolutions the spring appeared

to be wound up, and it then supported a weight of 1 lb., at 3 inches rad., with a variation of $\frac{1}{4}$ inch either way in the radius. The tension was in all cases proportional to the number of turns, and no set was apparent after unwinding.

It was expected in this test that a much lower result would be found than in the test for torsion, both on account of the higher modulus for bending, and also on account of the character of the stress in developing a smaller proportion of the inherent energy in the steel. But the result is surprising, for we have without doubt, 9.42 ft. lbs. in 605 grs., or 108 ft. lbs. per lb., and assuming the neutral axis to be in the middle of the ribbon, there must have been exerted a transverse resistance of 240,000 lbs. per square inch upon the outside fibres, and this too within the elastic limit.

To satisfy myself on this point, and to be sure that this remarkable strength was not due to the combination of superimposed layers, I fastened a short length of the spring between wooden clamps, one of which was fixed so as to use the spring as a cantilever to sustain weights attached to the other. In this way the spring supported a weight of 1 lb. at a radius of 4 inches, when an apparent set took place.

The transverse strength of the steel was thus found to be over 320,000 lbs., with an elastic limit closely approaching that amount.

The other spring, which was $\frac{1}{2}$ inch wide by .022 inches thick, and weighed 2,040 grs., showed even better results. After making twelve revolutions it sustained a weight of 2 lbs., at 6 inches rad., developing 45 ft. lbs. of work, or 154 ft. lbs. per lb., and showing a transverse elastic resistance of 300,000 lbs. per square inch. The energy developed by any layer of the spring is proportional to the square of its distance from the neutral axis, and we find by integration that the energy developed by flexure is one-third of that which is possible by direct tension or compression.

We should therefore expect to obtain from this steel, under tension or compression, 462 ft. lbs. of energy per lb. of steel, when strained up to 300,000 lbs. per square inch, and this gives for the modulus of flexure the value of 30,000,000.

This low modulus of elasticity, in connection with such a high

degree of transverse strength, seems to give new life to the project which at first appeared so hopeless, but it is still doubtful whether any great success can be anticipated under this more favorable light. Assuming 154 ft. lbs. per lb., which is probably far in excess of what can be obtained on a large scale, and allowing $\frac{1}{4}$ of the total weight for the weight of the springs, and 50 per cent. for the efficiency of the driving mechanism, we have about 20 ft. lbs. of available energy per lb. of load moved. On a level track or down grade this might be sufficient to run a mile, but it would be entirely inadequate to overcome ordinary grades, or to endure many stops, even if a portion of the energy were returned in stopping. The approach to Spring Garden Street Bridge, for instance, would doubtless prove insurmountable.

The experiment, however, will soon be tried, and the result, if unsuccessful, will at least be instructive. It is believed, in conclusion, that the results here given upon the resilience of steel are the highest yet recorded, notwithstanding the fact that they are constantly being realized in practice, and that the demonstration of their truth is within the reach of any one who will take the trouble to make it.

XVII.

THE MEANS EMPLOYED IN REPAIRING BELMONT SUBMERGED MAIN AT PHILADELPHIA.

By J. J. de Kinder, Member of the Club.

Read October 18th, 1884.

In the Spring of 1883, a serious leak was discovered in the submerged main which crosses the Schuylkill River south of and near the Columbia Bridge.

This main had been laid with ball and socket joints. Upon examination the diver found that, at a point about 150 feet from the east river bank, one of the bells had parted, allowing the male end to leave the bell, causing a large opening, through which the water from the Belmont Reservoir under a head of

over 200 feet escaped in such a volume that a hollow was scoured out of the river bed directly under, the opening of about 6 feet in depth and from 40 to 50 feet in diameter.

As the use of the main was imperative, to meet the demands of the summer months, it was decided to repair it without delay.

An attempt was made to force the male end back into the broken bell, the intention being to secure and strengthen the bell afterwards by means of heavy iron bands.

It was found, however, that the lead of the ball on the male end would not enter the bell; besides, any movement in this joint necessitated a corresponding movement in two additional joints, one on either side of the damaged joint, while the rust which had formed in that part of the bells not in immediate contact with the lead, prevented it from sliding into place without the application of enormous strains, which might have broken the two additional bells in preference to moving them.

It was then decided to remove the broken bell by means of light charges of dynamite, bringing the two successive lengths of pipe as near as possible into line, by moving several lengths of pipe on either side at one time and encase the broken part in a jacket or sleeve made of boiler iron, in two pieces, to be bolted together and strengthened furthermore with bands, etc., as shown in the plan.

This work was effectually accomplished; the hollow in the river bed under the main was filled in with stone and furnace slag, upon which willow mattresses were laid, weighted with more slag, thus making a good support for the main while preventing the possibility of scouring in the future.

It should be said in connection with this that the cause of the breakage explains itself, I think plausibly, in this way:

Some time before, a heavy ice gorge occurred at the Columbia Bridge on the upstream side of the main in question, then followed a severe freshet, and the water found no other outlet just there than close along the river bed. The consequent rush of it scoured the lighter material from under the main (for at that point, owing to the direction given it by the presence of a small island above the bridge, the current is always swiftest and the depth of water greatest), the main for a length of some 40 feet

lost its support, the bell end proved to be too weak to bear the weight unsupported and parted, when no doubt the leak thus caused in the main added its quota to the scouring process.

The sleeve worked admirably so long as the main was used simply for a gravity supply, but before long it became necessary to use it in connection with a 20,000,000 gallons engine at the Spring Garden pumping station. Unfortunately the supply main from this engine, connecting with the submerged main, is but 30 inches, and consequently entirely too small. The sleeve then felt the impact of each successive stroke of the pumps, a series of hammer blows, as it were, which caused some of the bolts to break. Heavy iron clamps or dogs were added, one between each two bolts.

This proved effective for some time, but in December following the sleeve burst, tearing and twisting the sheet iron, and the main was once more useless. Fortunately the summer was over and the danger of a short supply of water avoided.

The next plan shows the manner in which the main was again repaired this summer and the means employed to make these repairs.

Before proceeding I might add that the river bed is mostly rock, making it impossible to drive piles. Again, to construct a loaded coffer-dam encircling the damaged joint would require it to be large enough to take in so much of the river bed as was filled in with slag and mattresses, otherwise it would be impossible to make a tight connection with the bottom; this, then, would require a coffer-dam of some 50 feet in diameter at least. The difficulty of making such a structure tight under these circumstances, and keeping it tight and in position in the event of heavy freshets, let alone the great cost, is readily understood.

From material already on hand (it having been previously used for other work), a bottomless box was built, its general dimension being:

31 feet long,
10 " wide, } outside measurement,
25 " high,

long enough to take in over two lengths of pipe, wide enough

to straddle the pipe and leave ample space on either side of it to work, and of sufficient height to reach clear above the surface level of a 6 feet freshet.

Since the plan is drawn to scale it is unnecessary to go into the details of construction, and I will confine myself to a general outline of the work.

The box was built in three horizontal sections: the first one built on shore near the spot was sheathed vertically on the inside with 3 inch t. and g. spruce planks and horizontally on the outside. This outside planking was caulked and pitched. This section then was launched from ordinary ways and held suspended between two small lighters. The second section was then built upon and secured to it and the structure lowered until the upper sill was flush with the deck, then the third and last section was added, the dam floated over the damaged main into position, when it was finally lowered until it rested with the bottom sills on the river bed.

As shown in the plan, the ends of the lower section were left open for a height of seven feet, and only this section is sheathed on the inside. The first was done, not to ensure greater tightness, but simply to act as a continuous guide to a pair of loose sills, under and against which the loose floor was to rest.

By means of a diver the river bed, for a space about as large as required for the dam to rest on, had been levelled off, and when the dam finally rested on this fairly even surface—straddling the main—the floor and bulkheads for the ends of the lower section remained to be put in place. Using short, heavy timbers, chain slings and screws, the main was partly raised and the dam settled hard down on the bottom. This operation brought the underpart of the pipe high enough above the river bed, inside of the coffer-dam, to allow the floor to pass under it.

The sills marked *S* in the plan were connected at each end to vertical timber posts, *P*, let into the sill with a slack mortise, and secured each with one $\frac{3}{4}$ inch iron bolt, working freely in the hole. The sills, by means of these posts, were movable up or down, in guides which kept them snug up against the inside lining of the lower section.

By this arrangement, had the coffer-dam settled more at one

end than the other, the sills could be adjusted to meet this angle, and thus bring the floor parallel with the underpart of the main anyhow.

The position of the sills, *S*, having been determined, the upright posts, *P*, were bolted to the corner posts of the coffer-dam, and the work of putting in the floor commenced.

This floor was made up of dry white pine pieces, 6 inches by 8 inches by 7 feet 5 inches, previously fitted together. Each piece was laid in position under the sills, *SS*, separately, and the whole work carried on as rapidly as possible, in order that the floor might swell tight.

Once the floor in place, the bulkheads were put in the ends of the low section. These bulkheads had also been built previously of two thicknesses of 3 inch *t* and *g* plank laid crossways, and finally canvas was battened over the ends and lashed with a mast-hoop around the projecting pipe. Additional shores were bolted against the inside of the uprights of the dam, and resting on the loose sills, *S S*, to prevent buckling, and shores placed on the floor between the same sills to keep them up snug against the lining.

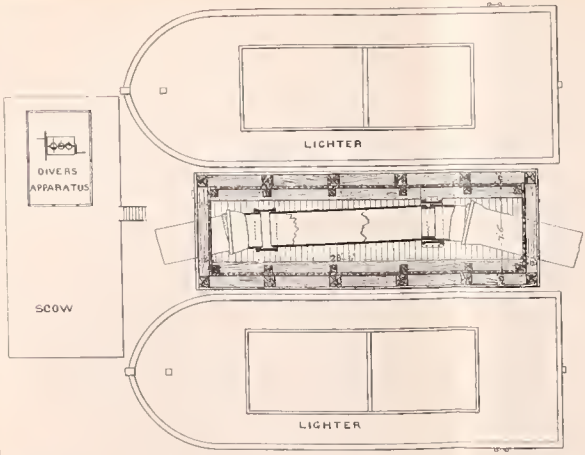
With this completed, the question is how to keep the dam down in place while the water is pumped out.

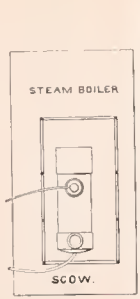
Three beams were laid across the top of the dam, to which, by means of chains and hawsers, lighters were swung one on either side.

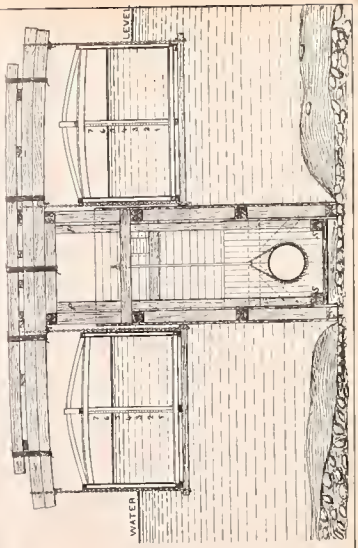
A small hatch, 8 inches square, was cut in the side of each lighter, also a hatch 18 inches square in either end of the dam. A batten, graduated in inches, was nailed to one of the piers of the Columbia Bridge near by, a similar one to the dam, and one to a post situated in the centre of each lighter.

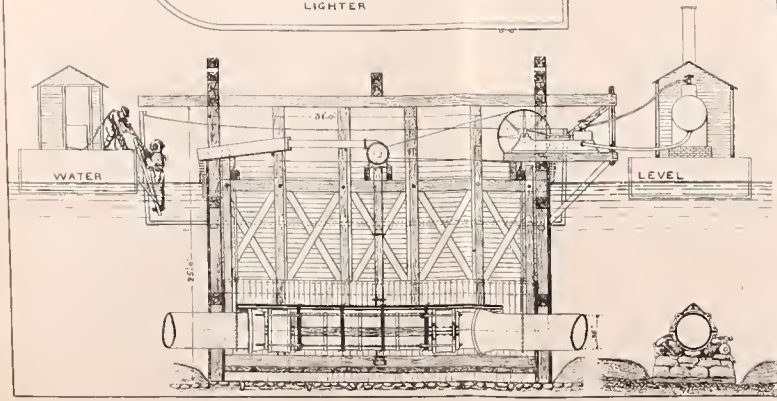
I then calculated the amount of water which each lighter was required to hold in order to counter-balance the buoyancy of the coffer-dam when empty. This water-line I made the zero mark on all four the battens.

If the river, during the operation, rose, I pumped more water into the lighters inch for inch, plus an allowance for the increasing buoyancy of the coffer-dam. When it fell I would lower the water level in the lighters accordingly, to prevent overstraining of the supporting beams. During heavy freshets I would fill the









PROC. ENG. CLUB OF PHILA. 1884. VOL. IV., NO. 4, PLATE XIII.

BALANCED FLOATING COFFER-DAM

FOR

REPAIRING SUBMERGED WATER PIPE,

DESIGNED AND BUILT FOR THE

BELMONT SUBMERGED MAIN,

PHILADELPHIA.

SCALE OF FEET

0 5 10 15 20 25

dam, open the hatches in the sides of the lighters and allow them to fill, thus preventing the possibility of their rising high enough to foul the supporting beams and raise the dam, while the presence of four hawsers, from the dam to the shore and bridge piers on the upstream side, made the risk under any circumstances very small.

An 8-inch Edwards cataract pump, with engine and boiler, completed the outfit.

Notwithstanding three freshets, two of which were uncommonly severe, the task was successfully accomplished. Of course, once started on the repairs of the main, with the dam empty, the work required pushing day and night without a break, while the height of the river surface needed continual watching.

When the repairs were completed the bulkheads were removed from the ends of the lower section, the loose floor ballasted with stone and sunk to the bottom, a bed composed of large stone and bags of hydraulic cement built upon it, firmly supporting the main, the chain slings supporting the main removed, and the coffer-dam floated away, after first removing the upper section and part of the middle section.

ON THE STRENGTH OF WROUGHT IRON COLUMNS.

(CONTINUATION)

By the Author, Thomas M. Cleemann, Member of the Club.

Read Nov. 1st, 1884.

More than three years ago (Proceedings Engineers' Club, Vol. 2, p. 105), the writer called the attention of the Club to the unsatisfactory condition of the existing knowledge of the strength of wrought iron columns, showing that according to the records of experiments then existing, a supposed constant in the accepted formula for calculating their strength did not seem to be constant at all. Since that time an interesting account of tests made on "Phœnix" columns was published in the "Transactions

of the American Society of Civil Engineeers," and discussed in our Proceedings, Vol. 3, p. 129. Finally, there has lately appeared in the same Transactions for April, an account of a very extensive series of experiments made by Mr. James Christie, a member of our Club, at the Pencoyd Iron Works. All of these on flat or fixed ended columns have been used for determining the most probable values of f and a in Rankine's formula by the method of least squares, with the following result:

	f	a	No. of experiments.
Angles, flat ends, . . .	41269	$\frac{1}{21160}$	42
" fixed " . . .	40935	$\frac{1}{25754}$	25
Tees, flat " . . .	42307	$\frac{1}{19476}$	37
Channels flat " . . .	35571	$\frac{1}{29968}$	35
Welded tubes, flat ends,	32427	$\frac{1}{46320}$	8
I beams, ...	44890	$\frac{1}{17978}$	3

These results seem to show that for shape iron we may perhaps after all regard a as a constant in the formula, and it is therefore suggested that for American iron it shall read:

$$\frac{P}{S} = \frac{40000}{1 + \frac{1}{25000}\,\frac{l^2}{r^2}}$$

the most probable values from the whole set of 150 experiments, regarding a as a constant, being $f = 39{,}426$ and $a = \frac{1}{24699}$. As the twenty experiments on Phœnix columns referred to above gave $f = 45408$ and $a = \frac{1}{28797}$, it seems that we can likewise use the same formula for built columns, when properly made, and be on the safe side. It merely remains to note that in the formulas for the square of the least radius of gyration given in the table at page 108 of our first volume, those for the angle and cross-shaped sections were calculated from the moments of inertia about axes parallel to their longer arms. This was wrong; the axes should have been parallel to the line joining the extremities of the longer and shorter arms. This correction will, of course, diminish the values of a as there given for these two shapes.

The true formulas have been worked out, and are of a very complicated form, but are greatly simplified when the legs are equal. They then become for the angle iron:

$$r^2 = \frac{1}{24}\left(b^2 - bt + \frac{11}{4}t^2\right)$$

and for the cross-shaped section:

$$r^2 = \frac{1}{12}\,\frac{b^3 + bt^2 - t^3}{2\,b - t}$$

In the August number of the *Transactions of the American Society of Civil Engineers* there is an account of some further experiments of Mr. Christie, this time on steel columns, principally of angle-iron shape. Twenty-seven experiments on these, made of mild steel, or that containing more than $\frac{15}{100}$ per cent. of carbon, gave values of f and a of 52394 and $\frac{1}{19432}$; and twenty-five on those of hard steel, or that containing $\frac{36}{100}$ per cent. of carbon, gave the values 82984 and $\frac{1}{12268}$.

DISCUSSION.

By Mr. James Christie.

The experiments first referred to by Mr. Cleemann were subsequently supplemented by the similar experiments on steel, and a basis established for the relations existing between steel and iron compression members for structures.

In addition to the practical results obtained, the experiments were of peculiar interest, inasmuch as they add additional confirmation to the ordinary theory of flexure as propounded by Euler a century ago. Experiments on beams of iron and various grades of steel, show a practically uniform elasticity, however different the materials may be in ultimate tenacity.

When the lengths of columns are so great in proportion to cross dimensions that failure will occur almost entirely by bending, then the elasticity of the material is the sole measure of its resistance, and the common theory of flexure will apply. The experiments showed that, when certain ratios of length to cross-section were reached, uniform resistance occurred between iron and steel, a fact, I believe, not heretofore known.

XVIII.

A FLOATING COFFER DAM.

By Edwin F. Smith, Member of the Club.

Read November 15th, 1884.

To facilitate the removal of rock obstructions, which required blasting, from certain river channels of the Schuylkill navigation in 1880, a floating coffer dam was used, a description of which may be of interest to members of the Engineers' Club.

The accompanying drawing shows the coffer dam in plan and section. The outside dimensions are 32 by 48 feet, and the inside 20 by 36 feet. These dimensions were fixed as a matter of convenience only, the dam being framed in two halves, cut longitudinally, as represented by the cross-section *A*, for the purpose of passing the locks of the navigation, the two cribs, when coupled end to end, making a float 96 feet long by 16 feet wide.

The peculiar features of this coffer dam consisted:

First.—In its being framed in two halves, as above described, thus affording facility for moving it long distances through the locks of an artificial navigation, and also for its use in laying the foundations for a bridge pier, or other similar structure, after which it could readily be removed, without injury to the dam itself, by uncoupling and removing each section.

Second.—The application of water-tight chambers or boxes to the crib, by means of which it was floated from one point to another, and greater facility afforded in setting it over obstructions. These boxes were also utilized to contain the stone with which the crib was settled to its proper position over or around an obstruction. The *modus operandi* was as follows: When the crib was being moved from one point to another, the water-tight chambers were pumped out, giving greater buoyancy to the crib. Having located it over an obstruction, the spuds *BB* were dropped and the plugs *C*, of which there was one to each chamber, removed, allowing them to fill with water. At the same time stone was piled on temporary platforms on the sides and ends of the crib until it was settled to the bottom. A submarine diver was

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PLATE XIV

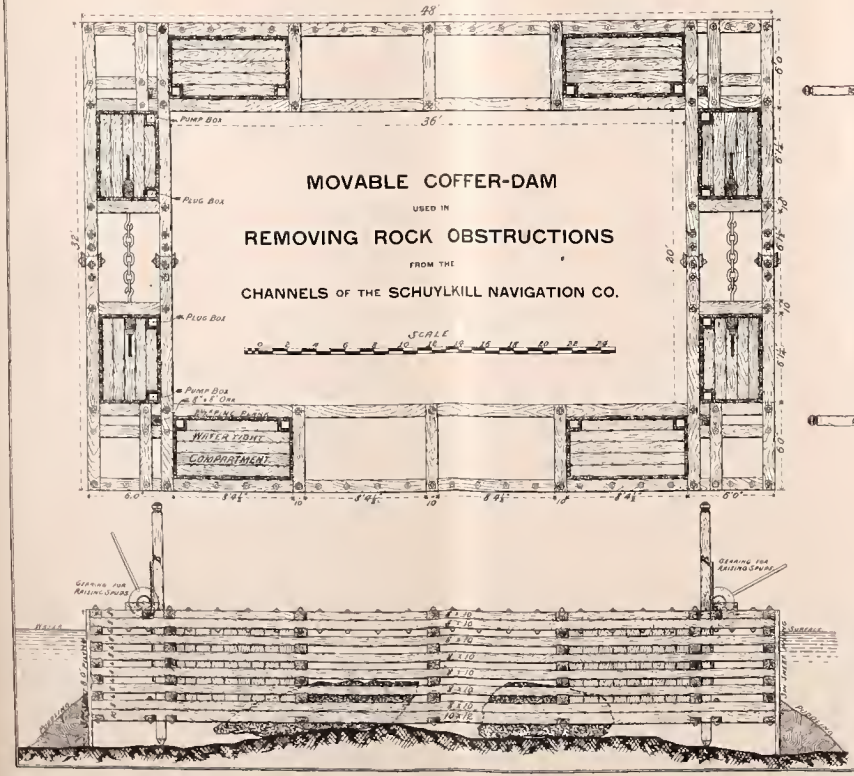
MOVABLE COFFER-DAM

USED IN

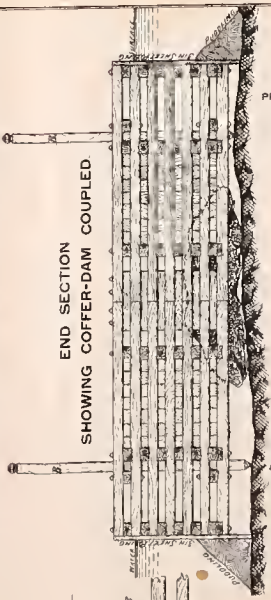
REMOVING ROCK OBSTRUCTIONS

FROM THE

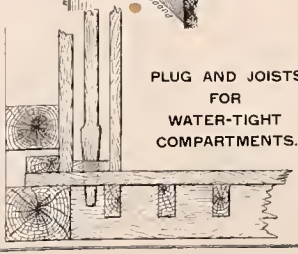
CHANNELS OF THE SCHUYLKILL NAVIGATION CO.



END SECTION
SHOWING COFFER-DAM COUPLED



SECTION SHOWING ONE-HALF OF DAM.



PLUG AND JOISTS
FOR
WATER-TIGHT
COMPARTMENTS.

then sent down to put in blocking of stone or wood at distances of about eight feet apart at all places where the inside and outside stringers stood off the rock. When this was done the chambers *DDD* were filled with stone and the dam was ready for sheet piling.

The thickness of the sheet piling was from three to four inches, according to the height of the bottom stringer from the rock, and all sheet piling was carefully fitted to the rock by the diver. Puddling of good, heavy, gravelly material was next dumped around the sheet piling and allowed to settle generally over night before pumping out the dam.

This coffer dam was operated, usually, in 7½ feet of water, but upon one occasion a depth of as much as 11 feet was encountered at one end and along one-half of one side, without causing any trouble. The permanent crib was framed 8 feet high.

The taking up of the dam was the reverse of the operation of setting it, the water-tight compartments being first pumped out and cleared of stone. The cost of the coffer dam complete was $1128.32, in 1879. It was used during the years 1880, 1881 and 1882, being shifted from one position to another a great many times, and is still in good order and fit for service. The same sheet piling was used over and over again, with the addition of 5 to 10 per cent. of new material for each shift. It was 3 and 4-inch white pine, jointed. The men became so well accustomed to shifting the dam, that *seven* men could make the shift, including pumping out ready for work, in 4 to 6 days, the average cost of four shifts being $86.19 for labor only. For pumping, a 6-inch Andrews centrifugal pump was used, and at some locations the sheet piling was so tight that very little pumping was done. Ordinarily the pump was run three minutes out of every ten. For the removal of rock, a steam drill was used, and all blasting was done with a battery.

As the dam was framed with cribs of only 6 feet thickness, it required bracing inside while it was being pumped out and during the prosecution of the work.

For moderate depths, this dam, it is believed, would answer every purpose where work is required upon a number of points in succession, and at a much less cost than the ordinary coffer

dam—two walls of posts, stringers and sheet piling with an interior filling of puddling, which is often very difficult and expensive to remove after the completion of any work.

FREDERICK COPLAND WOOTTEN.

Frederick Copland Wootten was the youngest son of Mr. John E. Wootten, General Manager of the Philadelphia & Reading Railroad Company. He was born in Philadelphia on the 18th of November, 1858. In his early childhood his parents removed to Reading, where his education was begun in the public schools. After graduating from the Reading High School he entered the Lehigh University in South Bethlehem, taking a course of mechanical and civil engineering.

He graduated in this department with the class of 1880, when he entered the service of the Pennsylvania Railroad Company. That he might qualify himself thoroughly for his work, and make himself acquainted with the practical details, as well as with the theory, of his profession, he entered the great shops of the company at Altoona. After completing his course in the shops, he was appointed to the position of assistant foreman of the locomotive department of the Pittsburg division, and had made so good a record that he was about to be advanced to a higher position, when the first symptoms of the disease, which finally carried him off, showed themselves.

He was taken dangerously ill, but recovered his strength sufficiently to be taken to his home in Reading on the 7th of January, 1884. Here, under the treatment of two physicians of the city, he recovered so far as to be able to appear on the street, and entertained a hope of being well enough, at an early day, to resume his duties. But it soon appeared that his life-work was done. Early in September he suffered a severe relapse, and, although he again rallied sufficiently to be able to join the family at table, he suddenly grew worse, and passed away on Sunday morning, November 16th.

He was enthusiastic in his profession, and had an honorable ambition to make himself complete master of all that related to it, both practical and theoretical. He was much interested in all discoveries and improvements connected with his business, and had already showed both disposition and ability for original study and investigation. He possessed a bright and thoughtful mind, which, together with his thoroughness and faithfulness in the discharge of his duties, gave reason to his friends to expect for him a high position among the members of that profession to whose ability and energy this country is so greatly indebted for its material development.

He was upright and honorable in character; in disposition, quiet and modest; in his bearing, manly and courteous.

He was a member of Christ (Episcopal) Cathedral, Reading; having been a member of its boy choir and its Sunday school, and after his return to his home he was, as long as his health permitted, a constant attendant upon its services. His funeral was attended by a large concourse of friends from Reading and elsewhere, including many of those with whom he was associated in the service of the Pennsylvania Railroad Company. His remains were laid to rest on the 20th of November, in the Charles Evans Cemetery. "Awaiting the general resurrection in the last day, and the life of the world to come."

NOTES AND COMMUNICATIONS.

A NEW PROCESS FOR THE MANUFACTURE OF PORTLAND CEMENT, AND OTHER HYDRAULIC CEMENTS, AND FOR THE UTILIZATION OF GRANULATED ORES.

Regular Meeting, February 2d, 1884.—Mr. E. F. Loiseau presented the following:

Limestone containing more than 10 per cent. silica, possesses, when burnt and made into a mortar, the peculiar property of hardening under water. Lime burnt from such limestone is termed *hydraulic* lime, and the mortar *hydraulic* mortar.

When unburnt hydraulic lime is a mixture of carbonate of lime with silica, or a silicate, generally silicate of alumina, the latter being insoluble in hydrochloric acid.

During the burning, the hydraulic lime undergoes a change similar to that taking place when a silicate insoluble in acid is precipitated, during the application of heat, with an alkaline carbonate. After burning, the lime is to a great extent soluble in hydrochloric acid, and has lost some of its carbonic acid.

It follows from this that an artificial hydraulic mortar can be prepared from ordinary lime by the addition of silica. This preparation is termed a *cement.* A few natural cements are found, and may be considered chiefly of volcanic formation, but the high price of natural cements, consequent upon the smallness of the quantity found, and the difficulty of working them, has given much encouragement to the manufacture of artificial cements.

To England is due the credit of having first introduced the manufacture of Portland cement on a large scale; and although other countries, especially France and Germany, have introduced its manufacture in certain limited localities, the peculiarly advantageous position of England, in having inexhaustible stores of the raw materials, in their cheapest and simplest conditions, coupled with the low price of fuel, enables that country to supply the article to every quarter of the globe.

Portland cement is a compound of argillo-calcareous, or argillo-magnesian substances, and may be made from natural rocks or earths wherein are found by analysis, the necessary proportion of silica, alumina, and lime or magnesia; or from a mixture of lime with clays of different kinds. It is usually made in two ways, known as the "wet," or "English" process, and the "dry," or "German" process, described as follows, by Prof. De Smedt:

1. *The wet process.*—In this process, the proper proportion of clay and chalk having been collected, are thrown into a pug mill, and water is added. The mixture is constantly stirred, and is allowed to flow out in a paste of about the consistency of cream, on to drying floors heated by steam, for the purpose of expelling the excess of water by artificial heat; or into "backs," or vats, in the open air, about two feet deep, where, by decantation and evaporation, all the water is drawn out. The paste thus formed is cut, when dry, into bricks or squares, about a foot to two feet square, and carried to the kilns. When placed in the kilns many of the pieces lose their corners, and much of the dry material is scaled off by reason of the intense heat, and the powder thus formed is wasted, as it mixes with the dust of the ashes. The square form, or squared sides of the bricks prevent draft, owing to their many points of contact. When drawn from the kilns the material is in the form of clinkers, in masses as large as a man's head, and in most cases covered with an unpenetrable vitrifaction or glaze, which is injurious to the manufacture of cement, and makes the grinding very difficult. The clinker drawn from the kilns is carefully examined, all vitrified pieces thrown out, the under-burned portion put in again, and the good clinker broken up and then ground and packed in barrels ready for market.

2. *The dry process.* In this process the chalk and clay, having been dried and powdered, are mixed together in a dry mixer in a dry state, and are then run into a pug mill, where just enough water is added to make a stiff paste. The material, as it exudes from the pug mill, is cut into bricks, loaded on cars, and carried to a drying-room, when, in about a week or two weeks' time, it is ready to be carried to the kiln. It is then burned, as in the "wet" process, ground and barreled. The same disadvantages of burning apply to this dry process as have been described as applying to the wet process.

Disadvantages of the wet system.—This system has the following disadvantages: 1st, the immense storage room required for the wet paste; 2d, the repeated handling required; 3d, the irregularity of the manufactured article, the paste run out on the backs being composed of materials of different specific gravities, the heavier naturally settling to the bottom; 4th, the large capital required to carry the stock of paste in the backs, the material requiring from two to four months to dry.

Disadvantages of the dry system.—1st. It requires one more handling and one more grinding than the wet; 2d, the large expense for drying floors; 3d, the large expense for fuel required in the drying operation.

Disadvantages incident to both systems.—1st. The handling of the material from the mixers to drying-floors or "backs," and then back to kilns; 2d, the waste of time and money before the mixed material can be used; 3d, the loss by wastage in the kilns; 4th, the difficulty of grinding the glazed clinker; 5th, the extra amount of coal required to send heat through the cold or only partly warmed masses of dried paste. It will be noticed that most, if not all, of these disadvantages are due directly or indirectly to the preliminary drying operation, which is performed before the calcining operation can take place.

Ordinary paste formed into bricks or other forms, if subjected, in the moist state, to a great heat, will fly apart and will all scale off into powder, leaving nothing behind, and consequently proper calcination is impossible. This effect is due to the sudden evaporation of the water contained in the bricks or pieces. The water, in its course toward evaporation, encountering an obstacle (the coating formed on the outside of the brick), breaks it in order to escape. This scaling off goes on continually until the whole piece is reduced to powder. It is for that reason that the paste is now thoroughly dried before calcining it—a process of great length and most expensive. The problem to determine is how to produce bricks or pieces in a moist state, of a sufficient porosity to allow the water of evaporation to escape during the calcining operation, without breaking the bricks into pieces or dust, and this result was obtained by Professor J. De Smedt, of Washington, D. C., by mixing hydrocarbons with the argillo-calcareous or argillo-magnesian material, prior to the calcining operation, and moulding the paste into bricks or forms. The lumps, in their moist state, may be taken at once from the mill or place where they are formed, and put into the kiln, no delay being necessary—in fact, the sooner they are put into the kiln the better. During the calcining operation, the combustible contained in the brick burns out gradually, and the brick is thus rendered porous little by little, according to the penetration of the combustion. The steam or vapor has thus afforded to it a free passage from the brick, and the latter preserves its form and shape unimpaired throughout the process of calcination. There is a noticeable absence of the surface glaze or vitrifaction, which usually appears on the calcined brick under ordinary methods, and, besides this, the calcination is more uniform and regular, by reason of the introduction throughout the brick of a heat-giving combustible. The bricks or forms, after calcination, are ground, and the product is packed in barrels in the usual way.

Professor De Smedt's invention possesses the following advantages over the methods of manufacture heretofore practiced. As compared with the wet system, it does away with the backs or vats, and the necessity for acres of storage-room. It lessens the amount of handling required, because it permits the paste to be run directly from the mixers to the kilns. It prevents the irregularity in the paste which results in the

wet system, from the settling of the heavier portions, and it lessens the outlay of capital required to carry the paste for months before it is ready for use. As compared with the dry process, it reduces the ordinary handling about one-third. It does away with drying-floors, and it also does away with the expense for fuel now required to dry the paste. As compared with both systems, it reduces the time required for manufacture from months in the wet system, and weeks in the dry system, to two or three days. It reduces to the minimum all loss by wastage and powdering in the kilns. It reduces cost of grinding, owing to the porosity of the clinker and the absence of the usual surface glaze or vitrifaction. It reduces the amount of fuel required to calcine the bricks, and it insures a regular and uniform product.

This process is applicable generally to all hydraulic cements in which the material is reduced to the condition of a paste before calcination.

After the destruction of the works of the Loiseau Fuel Company by fire, in March, 1883, Messrs. Lesley & Trinkle, of Philadelphia, purchased the mixer, the press, and other parts of the machinery, from the Phila. & Reading R. R. Co. The different machines were carefully repaired and were re-erected at the cement works, corner of Fairmount and Delaware Avenues, in this city. Messrs. Lesley & Trinkle having made with me satisfactory arrangements, I agreed to assist them in testing, on a large scale, Professor De Smedt's process. I mixed the ground rock with crude coal tar, adding a small quantity of water to form the paste, and this moulded well enough, but nothing but half lumps could be obtained. The coal tar by itself had not sufficient binding power to form a solid egg, and each moulding roller would carry off a half lump. I had devised a new feeding piece for the press, and the materials were delivered very regularly between the two moulding rollers, therefore I was satisfied that the trouble did not originate with the compressing machine, but could only be attributed to the condition of the materials when mixed. The mixture was very plastic and would stick to the shafts and blades in the mixer and to the shafts and blades in the hopper of the press. In order to render it coarser, I added to it a certain percentage of coke dust, which I thought would bind more firmly together the almost impalpable cement rock, and destroy its plasticity when mixed with the coal-tar and water. The result was very gratifying, and from that time the lumps left the moulds in their entirety.

The calcination of the lumps, conveyed directly from the press to the kiln without previous drying, was very successful, and demonstrated conclusively that Professor De Smedt's theory was correct. The egg-shaped form of the lumps facilitated the calcination and distributed the heat more evenly. It also required less time and a smaller quantity of fuel than by the old processes.

No improvements have been made in the manufacture of hydraulic cements for a number of years, but the improved method of Professor De Smedt has given such important results that they will no doubt create a radical change in that branch of industry.

These experiments have, moreover, demonstrated that, with my machinery, any kind of pulverized, granulated, or gritty material can be solidified in egg-shaped form, which is the most convenient for handling, and which leaves always between the lumps sufficient space for the free circulation of air or heat, and consequently for a free combustion.

Through the courtesy of Messrs. Lesley and Trinkle, I was also enabled to experi-

ment with granulated magnetite ore from the Phœnix Iron Company's "Hazy Vein," at Boyertown, Berks County. This fine ore cannot be roasted and but a small proportion of it is used raw in the furnace. It contains from 1 to 1½ per cent. of sulphur, as I am informed by Mr. John Hy. Harden, General Mining Engineer of the Phœnix Company.

The result of solidified shapes of the fine ore would enable it to be roasted, so that pig iron made from it would contain a smaller percentage of sulphur than at present. It would also utilize all the fine ore mined.

On examination I found that the ore contained sufficient argillaceous matter, and I merely mixed some water with the ore as it had been sent to me. The success was complete. I submitted the lumps to several degrees of heat, and they stood the fire without breaking. The roasting was perfect. In some lumps I brought the iron to the melting point, as the members will see by the lumps which I submit. Those experiments were made, under blast, in a portable forge and while the lumps of ore were still wet.

This last experiment demonstrates to a certainty that all the granulated ores can be solidified at very little expense (most of those ores containing argillaceous matter), and that the metals which they contain can thus be secured.

TABLES OF HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.*

ARTHUR WINSLOW, April 7th, 1883.

The formulæ used in the compution of the following tables were those given by Mr. Geo. J. Specht in an article on topographical surveying, published in Van Nostrand's *Engineering Magazine* for February, 1880.

These formulæ furnish expressions for horizontal distances and differences of level for stadia measurements, with the conditions that the stadia rod *be held vertical*, and the stadia wires be equidistant from the centre wire. They are as follows:

$$D = c \cos n + ak \cos^2 n;$$

$$Q = D \tan n = c \sin n + \frac{ak \sin 2n.}{2}$$

D = horizontal distance.
Q = difference of level.
c = the distance from the centre of the instrument to the centre of the object glass, plus the focal length of the object glass.
k = the focal length of the object glass divided by the distance of the stadia wires apart.
a = the reading on the stadia rod.
n = the vertical angle.
ak is the reading on the rod multiplied by k, which is a constant for each instrument (generally 100).

* A discussion of the theory of stadia measurements, written to accompany these tables, will be found in Report I, AA. of the Second Geological Survey of Pennsylvania, and also in Van Nostrand's *Engineering Magazine* for April, 1884, and in No. —— of Van Nostrand's *Science Series*.

In the tables the vertical columns consist of two series of numbers for each degree, which series represent respectively the different values of $ak \cos^2 n$ and $\frac{ak \sin 2n}{2}$ for every two minutes when $ak = 100$. To obtain the horizontal distance, or the difference of level in any case, the corresponding value of $c \cos n$, or $c \sin n$ must further be added, and the mean of each of these expressions for each degree, with three of the most common values of c, is given under each column.

As an example, let it be required to find the horizontal distance and the difference of level when $n = + 6° 18'$, $ak = 570$, and the instrument constant, $c = .75$. In the column headed 6°, opposite 18′, in the series for "Horizontal Distance," we find 98.80 as the expression for $ak \cos^2 n$, when $ak = 100$, therefore, when $ak = 570$,

$$ak \cos^2 n = 98.80 \times 5.70 = 563.16.$$

To this must be added $c \cos n$ which, in this case, is found in the subjoined column to be .75;

$$563.16 + .75 = 563.91$$

is then the required horizontal distance.

In a similar manner,

$$10.91 \times 5.70 + .08 = 62.27$$

is the required difference of level. One multiplication and one addition must be used in each case.

It is to be noticed that, with the smaller angles, $\cos n$ may be neglected in the expression $c \cos n$, and $c \sin n$ may be entirely neglected without appreciable error.

For values of c which differ from those given, an approximate correction, proportioned to the amount of differences, may very easily be made in these two expressions.

STADIA REDUCTION TABLE.

M.	0°		1°		2°		3°		4°		5°	
	Hor. Dist.	Diff Elv	Hor. Dist.	Diff Elv	Hor. Dist.	Diff Elv	Hor. Dist.	Diff Elv	Hor. Dist.	Diff Elv	Hor. Dist.	Diff. Elev.
0' . .	100 00	.00	99.97	1.74	99 88	3.49	99.73	5.23	99.51	6.96	99.24	8.68
2 . .	"	.06	"	1.80	99.87	3.55	99.72	5.28	"	7.02	99.23	8.74
4 . .	"	.12	"	1.86	"	3.60	99.71	5.34	99.50	7.07	99.22	8.80
6 . .	"	.17	99 96	1.92	"	3.66	"	5.40	99.49	7.13	99.21	8.85
8 . .	"	.23	"	1.98	99.86	3.72	99.70	5.46	99.48	7.19	99.20	8.91
10 . .	"	.29	"	2.04	"	3.78	99.69	5.52	99.47	7.25	99.19	8.97
12 . .	"	.35	"	2.09	99.85	3.84	"	5.57	99.46	7.30	99.18	9.03
14 . .	"	.41	99.95	2.15	"	3.90	99.68	5.63	"	7.36	99.17	9.08
16 . .	"	.47	"	2.21	99.84	3 95	"	5.69	99.45	7.42	99.16	9.14
18 . .	"	.52	"	2.27	"	4.01	99.67	5.75	99.44	7.48	99.15	9.20
20 . .	"	.58	"	2.33	99.83	4.07	99.66	5.80	99.43	7.53	99.14	9.25
22 . .	"	.64	99.94	2.38	"	4.13	"	5.86	99.42	7.59	99.13	9.31
24 . .	"	.70	"	2 44	99.82	4.18	99.65	5 92	99.41	7.65	99.11	9.37
26 . .	99.99	.76	"	2.50	"	4.24	99 64	5 98	99.40	7.71	99.10	9 43
28 . .	"	.81	99.93	2.56	99.81	4.30	99.63	6.04	99.39	7.76	99.09	9 48
30 . .	"	87	"	2.62	"	4.36	"	6.09	99.38	7.82	99.08	9.54
32 . .	"	.93	"	2.67	99.80	4.42	99.62	6.15	99.38	7.88	99.07	9.60
34 . .	"	99	"	2 73	"	4.48	"	6:21	99.37	7.94	99.06	9.65
36 . .	"	1 05	99.92	2.79	99.79	4.53	99.61	6.27	99.36	7.99	99.05	9.71
38 . .	"	1 11	"	2.85	"	4.59	99.60	6.33	99.35	8.05	99.04	9.77
40 . .	"	1.16	"	2.91	99.78	4.65	99.59	6.38	99.34	8.11	99.03	9.83
42 . .	"	1.22	99.91	2.97	"	4.71	"	6.44	99.33	8.17	99.01	9.88
44 . .	99.98	1.28	"	3.02	99.77	4.76	99.58	6.50	99.32	8.22	99.00	9.94
46 . .	"	1.34	99.90	3.08	"	4.82	99.57	6.56	99.31	8.28	98.99	10.00
48 . .	"	1 40	"	3.14	99.76	4.88	99.56	6.61	99.30	8.34	98.98	10.05
50 . .	"	1.45	"	3.20	"	4.94	"	6.67	99.29	8.40	98.97	10.11
52 . .	"	1.51	99.89	3.26	99.75	4.99	99.55	6.73	99.28	8.45	98.96	10.17
54 . .	"	1 57	"	3.31	99.74	5.05	99.54	6.78	99.27	8.51	98.94	10 22
56 . .	99.97	1.63	"	3.37	"	5.11	99.53	6.84	99.26	8.57	98.93	10.28
58 . .	"	1.69	99.88	3.43	99.73	5.17	99.52	6.90	99.25	8.63	98.92	10.34
60 . .	"	1.74	"	3.49	"	5.23	99.51	6.96	99.24	8.68	98.91	10.40
c = .75	.75	.01	.75	.02	.75	.03	.75	.05	.75	06	.75	.07
c = 1.00	1.00	.01	1.00	.03	1.00	.04	1.00	.06	1.00	.08	.99	.09
c = 1.25	1.25	.02	1.25	.03	1.25	.05	1.25	.08	1.25	.10	1.24	.12

STADIA REDUCTION TABLE.

M.	6°		7°		8°		9°		10°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′ . . .	98.91	10.40	98.51	12.10	98.06	13.78	97.55	15.45	96.98	17.10
2 . . .	98.90	10.45	98.50	12.15	98.05	13.84	97.53	15.51	96.96	17.16
4 . . .	98.88	10.51	98.48	12.21	98.03	13.89	97.52	15.56	96.94	17.21
6 . . .	98.87	10.57	98.47	12.26	98.01	13.95	97.50	15.62	96.92	17.26
8 . . .	98.86	10.62	98.46	12.32	98.00	14.01	97.48	15.67	96.90	17.32
10 . . .	98.85	10.68	98.44	12.38	97.98	14.06	97.46	15.73	96.88	17.37
12 . . .	98.83	10.74	98.43	12.43	97.97	14.12	97.44	15.78	96.86	17.43
14 . . .	98.82	10.79	98.41	12.49	97.95	14.17	97.43	15.84	96.84	17.48
16 . . .	98.81	10.85	98.40	12.55	97.93	14.23	97.41	15.89	96.82	17.54
18 . . .	98.80	10.91	98.39	12.60	97.92	14.28	97.39	15.95	96.80	17.59
20 . . .	98.78	10.96	98.37	12.66	97.90	14.34	97.37	16.00	96.78	17.65
22 . . .	98.77	11.02	98.36	12.72	97.88	14.40	97.35	16.06	96.76	17.70
24 . . .	98.76	11.08	98.34	12.77	97.87	14.45	97.33	16.11	96.74	17.76
26 . . .	98.74	11.13	98.33	12.83	97.85	14.51	97.31	16.17	96.72	17.81
28 . . .	98.73	11.19	98.31	12.88	97.83	14.56	97.29	16.22	96.70	17.86
30 . . .	98.72	11.25	98.29	12.94	97.82	14.62	97.28	16.28	96.68	17.92
32 . . .	98.71	11.30	98.28	13.00	97.80	14.67	97.26	16.33	96.66	17.97
34 . . .	98.69	11.36	98.27	13.05	97.78	14.73	97.24	16.39	96.64	18.03
36 . . .	98.68	11.42	98.25	13.11	97.76	14.79	97.22	16.44	96.62	18.08
38 . . .	98.67	11.47	98.24	13.17	97.75	14.84	97.20	16.50	96.60	18.14
40 . . .	98.65	11.53	98.22	13.22	97.73	14.90	97.18	16.55	96.57	18.19
42 . . .	98.64	11.59	98.20	13.28	97.71	14.95	97.16	16.61	96.55	18.24
44 . . .	98.63	11.64	98.19	13.33	97.69	15.01	97.14	16.66	96.53	18.30
46 . . .	98.61	11.70	98.17	13.39	97.68	15.06	97.12	16.72	96.51	18.35
48 . . .	98.60	11.76	98.16	13.45	97.66	15.12	97.10	16.77	96.49	18.41
50 . . .	98.58	11.81	98.14	13.50	97.64	15.17	97.08	16.83	96.47	18.46
52 . . .	98.57	11.87	98.13	13.56	97.62	15.23	97.06	16.88	96.45	18.51
54 . . .	98.56	11.93	98.11	13.61	97.61	15.28	97.04	16.94	96.42	18.57
56 . . .	98.54	11.98	98.10	13.67	97.59	15.34	97.02	16.99	96.40	18.62
58 . . .	98.53	12.04	98.08	13.73	97.57	15.40	97.00	17.05	96.38	18.68
60 . . .	98.51	12.10	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
c = .75	.75	.08	.74	.10	.74	.11	.74	.12	.74	.14
c = 1.00	.99	.11	.99	.13	.99	.15	.99	.16	.98	.18
c = 1.25	1.24	.14	1.24	.16	1.23	.18	1.23	.21	1.23	.23

STADIA REDUCTION TABLE.

M.	11°		12°		13°		14°		15°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′ . . .	96.36	18.73	95.68	20.34	94.94	21.92	94 15	23.47	93.30	25.00
2 . . .	96.34	18.78	95.65	20.39	94.91	21.97	94 12	23.52	93.27	25.05
4 . . .	96.32	18.84	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6 . . .	96.29	18.89	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8 . . .	96.27	18.95	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10 . . .	96.25	19.00	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12 . . .	96.23	19.05	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14 . . .	96.21	19.11	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16 . . .	96.18	19.16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18 . . .	96.16	19.21	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20 . . .	96.14	19.27	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22 . . .	96.12	19.32	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24 . . .	96.09	19.38	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26 . . .	96.07	19.43	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28 . . .	96.05	19.48	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30 . . .	96.03	19.54	95.32	21.13	94.55	22.70	93.73	24 24	92.86	25.75
32 . . .	96.00	19.59	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34 . . .	95.98	19.64	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36 . . .	95.96	19.70	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38 . . .	95.93	19.75	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40 . . .	95.91	19.80	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42 . . .	95.89	19.86	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44 . . .	95.86	19.91	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46 . . .	95.84	19.96	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48 . . .	95.82	20.02	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26 20
50 . . .	95.79	20.07	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52 . . .	95.77	20.12	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54 . . .	95.75	20 18	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56 . . .	95.72	20.23	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58 . . .	95.70	20.28	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60 . . .	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c = .75	.73	.15	.73	.16	.73	.17	.73	.19	.72	.20
c = 1.00	.98	.20	.98	.22	.97	.23	.97	.25	.96	.27
c = 1.25	1.22	.25	1.22	.27	1.21	.29	1.21	.31	1.20	.34

STADIA REDUCTION TABLE.

M.	16°		17°		18°		19°		20°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′ . . .	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
2 . . .	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83	88.26	32.18
4 . . .	92.34	26.69	91.39	28.06	90.38	29.48	89.33	30.87	88.23	32.23
6 . . .	92.31	26.64	91.35	28.10	90.35	29.53	89 29	30.92	88.19	32.27
8 . . .	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97	88.15	32.32
10 . . .	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01	88.11	32.36
12 . . .	92.22	26.79	91.26	28.25	90.24	29 67	89.18	31.06	88.08	32.41
14 . . .	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10	88.04	32.45
16 . . .	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15	88.00	32.49
18 . . .	92.12	26 94	91.16	28.39	90.14	29.81	89.08	31.19	87.96	32.54
20 . . .	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24	87.93	32.58
22 . . .	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28	87.89	32.63
24 . . .	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33	87.85	32.67
26 . . .	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38	87.81	32.72
28 . . .	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42	87.77	32.76
30 . . .	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47	87.74	32.80
32 . . .	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51	87.70	32.85
34 . . .	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56	87.66	32.89
36 . . .	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60	87.62	32.93
38 . . .	91.81	27 43	90.82	28.87	89.79	30.28	88.71	31.65	87.58	32.98
40 . . .	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69	87.54	33.02
42 . . .	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74	87.51	33.07
44 . . .	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78	87.47	33.11
46 . . .	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83	87.43	33.15
48 . . .	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31 87	87.39	33.20
50 . . .	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92	87.35	33.24
52 . . .	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96	87.31	33.28
54 . . .	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01	87.27	33.33
56 . . .	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05	87.24	33.37
58 . . .	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09	87.20	33.41
60 . . .	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14	87.16	33.46
c = .75	.72	.21	.72	.23	.71	.24	.71	.25	.70	.26
c = 1.00	.96	.28	.95	.30	.95	.32	.94	.33	.94	.35
c = 1.25	1.20	.36	1.19	.38	1.19	.40	1.18	.42	1.17	.34

STADIA REDUCTION TABLE.

M.	21°		22°		23°		24°		25°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff Elev.	Hor. Dist.	Diff. Elev.
0′ . . .	87.16	33.46	85 97	34.73	84.73	35.97	83.46	37.16	82.14	38.30
2 . . .	87.12	33.50	85.93	34.77	84.69	36.01	83.41	37.20	82.09	38.34
4 . . .	87.08	33.54	85.89	34.82	84.65	36.05	83.37	37.23	82.05	38.38
6 . . .	87.04	33.59	85.85	34.86	84.61	36.09	83.33	37.27	82.01	38.41
8 . . .	87.00	33.63	85.80	34.90	84.57	36.13	83.28	37.31	81.96	38.45
10 . . .	86.96	33.67	85.76	34.94	84.52	36.17	83.24	37.35	81.92	38.49
12 . . .	86.92	33.72	85.72	34.98	84.48	36.21	83.20	37.39	81.87	38.53
14 . . .	86.88	33.76	85.68	35.02	84.44	36.25	83.15	37.43	81.83	38.56
16 . . .	86.84	33.80	85.64	35.07	84.40	36.29	83.11	37.47	81.78	38.60
18 . . .	86.80	33.84	85.60	35.11	84.35	36.33	83.07	37.51	81.74	38.64
20 . . .	86.77	33.89	85.56	35.15	84.31	36.37	83.02	37.54	81.69	38.67
22 . . .	86.73	33.93	85.52	35.19	84.27	36.41	82.98	37.58	81.65	38.71
24 . . .	86.69	33.97	85.48	35.23	84.23	36.45	82.93	37.62	81.60	38.75
26 . . .	86.65	34.01	85.44	35.27	84.18	36.49	82.89	37.66	81.56	38.78
28 . . .	86.61	34.06	85.40	35.31	84.14	36.53	82.85	37.70	81.51	38.82
30 . . .	86.57	34.10	85.36	35.36	84.10	36.57	82.80	37.74	81.47	38.86
32 . . .	86.53	34.14	85.31	35.40	84.06	36.61	82.76	37.77	81.42	38.89
34 . . .	86.49	34.18	85.27	35.44	84.01	36.65	82.72	37.81	81.38	38.93
36 . . .	86.45	34.23	85.23	35.48	83.97	36.69	82.67	37.85	81.33	38.97
38 . . .	86.41	34.27	85.19	35.52	83.93	36.73	82.63	37.89	81.28	39.00
40 . . .	86.37	34.31	85.15	35.56	83.89	36.77	82.58	37.93	81.24	39.04
42 . . .	86.33	34.35	85.11	35.60	83.84	36.80	82.54	37.96	81.19	39.08
44 . . .	86.29	34.40	85.07	35.64	83.80	36.84	82.49	38.00	81.15	39.11
46 . . .	86.25	34.44	85.02	35.68	83.76	36.88	82.45	38.04	81.10	39.15
48 . . .	86.21	34.48	84.98	35.72	83.72	36.92	82.41	38.08	81.06	39.18
50 . . .	86.17	34.52	84.94	35.76	83.67	36.96	82.36	38.11	81.01	39.22
52 . . .	86.13	34.57	84.90	35.80	83.63	37.00	82.32	38.15	80.97	39.26
54 . . .	86.09	34.61	84.86	35.85	83.59	37.04	82.27	38.19	80.92	39.29
56 . . .	86.05	34.65	84.82	35.89	83.54	37.08	82.23	38.23	80.87	39.33
58 . . .	86.01	34.69	84.77	35.93	83.50	37.12	82.18	38.26	80.83	39.36
60 . . .	85.97	34.73	84.73	35.97	83.46	37.16	82.14	38.30	80.78	39.40
c = .75	.70	.27	.69	.29	.69	.30	.68	.31	.68	.32
c = 1.00	.93	.37	.92	.38	.92	.40	.91	.41	.90	.43
c = 1.25	1.16	.46	1.15	.48	1.15	.50	1.14	.52	1.13	.54

STADIA REDUCTION TABLE.

M.	26°		27°		28°		29°		30°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′ . . .	80.78	39.40	79.39	40.45	77.96	41.45	76.50	42.40	75.00	43.30
2 . . .	80.74	39.44	79.34	40.49	77.91	41.48	76.45	42.43	74.95	43.33
4 . . .	80.69	39.47	79.30	40.52	77.86	41.52	76.40	42.46	74.90	43.36
6 . . .	80.65	39.51	79.25	40.55	77.81	41.55	76.35	42.49	74.85	43.39
8 . . .	80.60	39.54	79.20	40.59	77.77	41.58	76.30	42.53	74.80	43.42
10 . . .	80.55	39.58	79.15	40.62	77.72	41.61	76.25	42.56	74.75	43.45
12 . . .	80.51	39.61	79.11	40.66	77.67	41.65	76.20	42.59	74.70	43.47
14 . . .	80.46	39.65	79.06	40.69	77.62	41.68	76.15	42.62	74.65	43.50
16 . . .	80.41	39.69	79.01	40.72	77.57	41.71	76.10	42.65	74.60	43.53
18 . . .	80.37	39.72	78.96	40.76	77.52	41.74	76.05	42.68	74.55	43.56
20 . . .	80.32	39.76	78.92	40.79	77.48	41.77	76.00	42.71	74.49	43.59
22 . . .	80.28	39.79	78.87	40.82	77.42	41.81	75.95	42.74	74.44	43.62
24 . . .	80.23	39.83	78.82	40.86	77.38	41.84	75.90	42.77	74.39	43.65
26 . . .	80.18	39.86	78.77	40.89	77.33	41.87	75.85	42.80	74.34	43.67
28 . . .	80.14	39.90	78.73	40.92	77.28	41.90	75.80	42.83	74.29	43.70
30 . . .	80.09	39.93	78.68	40.96	77.23	41.93	75.75	42.86	74.24	43.73
32 . . .	80.04	39.97	78.63	40.99	77.18	41.97	75.70	42.89	74.19	43.76
34 . . .	80.00	40.00	78.58	41.02	77.13	42.00	75.65	42.92	74.14	43.79
36 . . .	79.95	40.04	78.54	41.06	77.09	42.03	75.60	42.95	74.09	43.82
38 . . .	79.90	40.07	78.49	41.09	77.04	42.06	75.55	42.98	74.04	43.84
40 . . .	79.86	40.11	78.44	41.12	76.99	42.09	75.50	43.01	73.99	43.87
42 . . .	79.81	40.14	78.39	41.16	76.94	42.12	75.45	43.04	73.93	43.90
44 . . .	79.76	40.18	78.34	41.19	76.89	42.15	75.40	43.07	73.88	43.93
46 . . .	79.72	40.21	78.30	41.22	76.84	42.19	75.35	43.10	73.83	43.95
48 . . .	79.67	40.24	78.25	41.26	76.79	42.22	75.30	43.13	73.78	43.98
50 . . .	79.62	40.28	78.20	41.29	76.74	42.25	75.25	43.16	73.73	44.01
52 . . .	79.58	40.31	78.15	41.32	76.69	42.28	75.20	43.18	73.68	44.04
54 . . .	79.53	40.35	78.10	41.35	76.64	42.31	75.15	43.21	73.63	44.07
56 . . .	79.48	40.38	78.06	41.39	76.59	42.34	75.10	43.24	73.58	44.09
58 . . .	79.44	40.42	78.01	41.42	76.55	42.37	75.05	43.27	73.52	44.12
60 . . .	79.39	40.45	77.96	41.45	76.50	42.40	75.00	43.30	73.47	44.15
c = .75	.67	.33	.66	.35	.66	.36	.65	.37	.65	.38
c = 1.00	.89	.45	.89	.46	.88	.48	.87	.49	.86	.51
c = 1.25	1.12	.56	1.11	.58	1.10	.60	1.09	.62	1.08	.64

ABSTRACT OF MINUTES OF MEETINGS.

Of the Club.

May 3d, 1884.—Regular meeting.—Vice President J. J. de Kinder in the chair; 32 members and 6 visitors present.

Mr. S. N. Stewart, visitor, exhibited a model of his River or Current Motor. Paddles are placed upon cranks and maintained in a vertical position by long floating vanes or tails. The cranks are placed upon posts, rafts or boats in the stream and journaled at the water-line, thus keeping one-half of the paddle surface in action, while the common floating-wheel or current-wheel only keeps one-tenth of its surface in action. In Mr. Stewart's motor a 10 ft. arm carries a paddle 10 ft. high. For particulars concerning this engine, he refers to "Commercial Relations of the U. S.," 1881, p. 682, or *N. Y. Daily Tribune*, June 21st, 1881. Mr. Stewart said "the only way to utilize the power of large rivers is by current motors, for dams are not permitted and are too expensive; that a current of five miles an hour has one hundred times the pressure of wind at ten miles an hour, and that, as the current soon regains its normal velocity, it can be used over and over."

Mr. Thomas M. Cleemann read a paper, illustrated by model, on an Economical Form of Bridge Truss.

Mr. C. Henry Roney exhibited a section of four-inch Wooden Water Pipe and Joint, found about two feet below the surface while excavating a trench for the conduit of the Philadelphia Sectional Electric Underground Company.

Mr. W. G. Neilson read some notes on the recently published Report of the Gun Foundry Board. The recommendations embodied in this report, in regard to the establishment of a gun factory at Watervliet Arsenal, West Troy, New York, for the manufacture of guns for the Army, and at the Washington Navy Yard for the Navy, and that the Government should depend upon the steel manufacturers of the country for its forged steel and should simply finish the guns in its factories, were referred to, as also were the interesting facts collated by the Board, during their visit to Europe, in regard to the character of steel used for guns.

The Secretary exhibited, for Mr. J. H. Harden, a neat Topographical Model of the Jones Iron Ore Mine in Berks Co., Pa., and briefly explained the method by which such models are constructed.

MAY 17TH, 1884. Special Business Meeting.—Vice President J. J. de Kinder in the chair; 28 members and 4 visitors present.

The Secretary presented, for Mr. Edward Parrish, an illustrated account of the Effect of Sea Water on the Iron of Brandywine Shoal Lighthouse.

The Secretary presented, for Mr. Samuel Rea, "A Treatise on Bridge Architecture in which the Superior Advantages of the Flying Pendent Lever Bridge are Fully Proved," by Thomas Pope, New York, 1811, with Mr. Rea's comments thereupon.

Prof. L. M. Haupt read an illustrated paper on Rapid Transit.

Mr. Wm. H. Ridgway read a paper upon the Action of Water in the Modern Turbine, claiming that it is nothing more than an improved Barker's Mill, and that there is no such thing as the water spurting through the shutes and impinging on the buckets, as is generally believed, the wheel, on the contrary, taking a velocity very much greater than that of the inflowing water.

Mr. J. J. de Kinder presented an illustrated description of a method of Removing Condemned Machinery by Dynamite.

The following contributions to the Club Reference Book were submitted:

Tables of Turnouts from Tangents and Insides of Curves, by Mr. Theodore Low, C. E., Correspondent.

Table of Approximate Numbers to Facilitate Multiplication and Division, by Mr. Frederic Graff.

Some Properties of Numbers, by Mr. W. G. Neilson.

Spring of Rails in Inches, Chord 10 ft. Long, by Mr. Edward Samuel.

Table of Wheel Bases for Turntables, by Mr. Edward Samuel.

The Tellers of Election, Messrs. Codman and Bankson, reported that one hundred votes had been cast, and the following gentleman elected Active Members of the Club:

John H. Converse, W. Henry Sayen, I. Norris DeHaven, Alter Megear, Benj. P. Howell, T. A. M. Matsdaira, R. W. Davenport,

John N. Pott, J. B. Wilson, Walter C. Brooke, W. Brooks Cabot, Gaylord Thompson, Wm. P. Henszey, and Archibald Stevenson.

The Secretary announced that the Editors of the *Railway Age* had requested the Club to furnish an answer to the Howe Truss Bridge Problem, which had occupied the attention of that journal of late. The Secretary had sent a reply.

Votes of thanks were returned to Mr. B. Ayres, of Philadelphia, and Mr. Samuel Rea, Member of the Club, for special contributions to the library.

The matter of the Club taking part in the election of Trustees for the State College of Pennsylvania, was, on motion of Prof. Haupt, referred to the Board of Directors with power to act.

The Secretary explained that the applications for Reference Book sheets, which had been issued to members, were only for *extra* copies of the same, several members having misunderstood their intention.

June 7th, 1884.—Regular Meeting.—President Wm. Ludlow in the chair; 27 members and 3 visitors present.

The President announced, in relation to the question of new and enlarged quarters for the Club, that a house could be obtained in the Fall, in Girard Street, and requested the members to be prepared to discuss and act upon the subject at the next meeting.

Mr. Wm. H. Ridgway described a simple Crane, consisting of a cylinder hung from the jibs of an ordinary foundry crane and using the steam directly to hoist the load; and also an Elevator, in which water, receiving pressure from the direct application of steam acting upon a piston carrying a rack, gave motion to a shaft carrying a pinion and drum wheel.

Mr. C. Henry Roney exhibited specimens of American Sectional Electric Underground Conduits as Laid in Philadelphia, described the method of their construction in detail, the difficulties encountered in avoiding the present underground works, the manner of introducing and arranging the wires, and the behavior of the electric currents therein.

Prof. L. M. Haupt supplemented his paper of May 17th, upon Rapid Transit, by an interesting collection of statistics of the growth of the city from the time of the "pack horse" to the

present, and showed by maps that his previous statements were verified by these statistics.

Mr. A. E. Lehman exhibited to the Club a model of a new Protractor, and described the invention and the improvements he has made in it. It consists of a combination of protractor, T square, scales, etc., which may be worked separately or together. As a protractor only, it is complete, being graduated to degrees and fractions thereof and provided with a vernier reading to three minutes. It can be used, like an ordinary paper or ivory protractor, for hasty plotting, and combines triangles and scales in one instrument. For careful and precise work it is said to be equal to the best special instrument and to be no higher in price.

Mr. E. V. d'Invilliers read a paper on "Some Characteristics and the Mode of Occurrence of the Brown Hematite (Limonite) Ores in Central Pennsylvania."

Prof. L. M. Haupt called the attention of the Club to a bill, pending in Congress, to consolidate the U. S. Coast and Geodetic Survey with the Navy Department.

Captain S. C. McCorkle of the Coast Survey, who was present, explained the effect that its passage would have upon the future of the work, and President William Ludlow gave, from his own experience and knowledge, the reasons why this change was contemplated. The Secretary read his correspondence with Hon. Samuel J. Randall upon the subject, and expressed what he believes to be the unanimous sentiment of the Civil Engineering profession of the country, against any interference with a Survey, the perfection of whose results is proverbial, and against any increase of the already unwise and unjust discrimination of the Government against thoroughly competent *Civil* Engineers, and in favor of a class whose only claim (with *notable* exceptions) is that the Government has attempted to educate them and must, therefore, seem to provide them with something to do.

As no action could be taken until the next Business Meeting, the Chair appointed Prof. L. M. Haupt, Mr. Rudolph Hering and the Secretary, a Committee to prepare a Resolution upon the subject for presentation to the Club at that meeting.

June 21st, 1884.—Special Business Meeting. President Wm. Ludlow in the chair; 31 members and 2 visitors present.

The Secretary stated that, this being the last meeting until the Fall, determinate action would have to be taken by the Club with regard to arranging for the new Club House, as the lease of these rooms expires on December 1st, and three months' notice must be given. The President announced that the result of the inquiries made by the Committee of the Board of Directors (Messrs. Frederic Graff, Henry G. Morris and Col. William Ludlow, Chairman), seemed to point to one of the Girard Estate buildings, on Girard Street, between Eleventh and Twelfth, as the most central and suitable for our purposes, and that possession thereof could be had about October next.

Mr. Horace See moved that the Board be requested to lease the same and to notify the present landlord of the Club. The Secretary read a letter from Mr. Edward Samuel, advocating the purchase, and improvement by the Club, of a building somewhat further westward.

After favorable discussion of Mr. See's motion by Messrs. Ashburner, Strong, Graff and W. B. Smith, it was unanimously carried.

Prof. L. M. Haupt, Chairman of Committee on Resolution with regard to the proposed change in the United States Coast and Geodetic Survey, reported the following, which were unanimously adopted and the Committee discharged.

WHEREAS, *We, the Engineers' Club of Philadelphia, have learned that a bill has been drafted in the sub-committee on Sundry Civil Appropriations of the United States House of Representatives, the purport of which is to merge the United States Coast and Geodetic Survey into the Navy and Interior Departments,*

AND WHEREAS, *Under existing laws and regulations, such a practical dissolution of this distinguished and efficient organization must result in a lowering of the high standard attained, without producing any equivalent on the score of economy or expediency,*

AND WHEREAS, *The changes now proposed were tested, both in* 1834 *and* 1851, *and in each instance proved a failure, therefore it is*

RESOLVED; *That in the opinion of the members of this organization the proposed change in the status of the United States Coast and Geodetic Survey would be prejudicial to the best interests of the Government Service.*

RESOLVED; *That the Members of Congress representing the State of Pennsylvania be, and are hereby, respectfully and earnestly requested to oppose the passage of this bill.*

(The Secretary having arranged therefor, copies of the above were forwarded immediately after the meeting.)

The Secretary reported upon the relations of the Club to the Custom House and Post Office, but delays his final report, as certain matters in relation thereto are still subject to controversy. Documentary and other evidence is on file, however, to show that the following are among the remarkable conclusions which have been reached by our government officials.

By the Custom House:

1*st.* *That engineering societies, the objects of which are "the professional improvement of its Members, the encouragement of social intercourse among men of practical science and the advancement of engineering in its several branches," are* NOT *philosophical societies.*

2*d.* *That the liability of a package to duty depends upon its* SIZE.

3*d.* *That the Transactions of the Institution of Civil Engineers of England* ARE *subject to customs duty, and that the Transactions of the North of England Institute of Mining and Mechanical Engineers* ARE NOT.

4*th.* *That the Transactions of the Institution of Civil Engineers of England are worth about* THREE CENTS EACH. (Sic transit "ad valorem" mundi!)

By the Post Office:

1*st.* *That, while* TWO *cents per pound is the rate accorded to the general press, including certain pictorials about which all respectable people seem to have one opinion, a Society, the object of which is the dissemination of useful knowledge, must pay one cent for each two ounces and* FRACTION THEREOF, *or over* EIGHT *cents per pound, on a publication issued as its own proceedings.*

2*d.* *That this Society is not entitled to "*THE SAME LOW RATES THAT ARE EXTENDED TO THE GENERAL PUBLIC," *under the recent law, making one cent for* FOUR *ounces, the rate at which an individual can post a newspaper.*

The report of the Secretary was referred to the Board with power to act.

On motion of Mr. C. A. Ashburner, the Club Rooms were unanimously tendered to the Local Committee of the American Institute of Mining Engineers for their headquarters.

The Tellers of Election reported that 113 votes had been cast and the following gentlemen elected Active Members of the Club: Messrs. Eckley B. Coxe, Wm. H. Robinson, Robt. L. Holliday, Jos. M. Wilson, Mataro Crizuka, Edwin Chamberlain, John W. Cloud, James F. Wood, Wm. Sellers, S. N. Stewart,

A. R. Faunt Le Roy, Wm. H. Jones, T. Benton Brown, Oscar Sanne, Wm. H. Dechant and W. H. Heuer.

Mr. Horace See presented copies of Indicator Cards from the engines of the yacht "Anthracite," taken with 370 pounds boiler pressure per square inch, and S. S. "Aberdeen" with 113 pounds; also a diagram showing curve of initial pressure of steam in the high pressure cylinder of each vessel.

Mr. J. E. Codman exhibited and explained drawings of the New Steel Boilers for the Philadelphia Water Department.

Mr. Chas. A. Ashburner presented a description of the Anthracite Coal Fields, accompanied by a geological map of the region. He also presented to the Club a very fine shaded lithograph of the topography of McKean County, Pennsylvania.

Prof. L. M. Haupt added to his recent papers on Rapid Transit, statistics of the Growth of Cities as exemplified in Philadelphia.

The Secretary presented Mr. John Marston's reply to Mr. J. H. Murphy's discussion of the Formulæ of Turnouts and Crossings, presented by him to the Reference Book.

The Secretary also presented the following Reference Book contributions: A Coördinate Method of Ascertaining Distances in Cities, Applied to Philadelphia, by Mr. John H. Dye; Relative Elevations of Certain Leveling Data, by the Secretary.

The Club adjourned for the Summer, to meet at the call of the President.

October 4th, 1884.—Business Meeting.—Past President Frederic Graff in the chair; 21 members present.

The Board of Directors presented their minutes as the report of routine business transacted since last Business Meeting, and made special report of a communication from the Board of Managers of the Association of Engineering Societies. This communication cordially invited the Club to unite with the Association and publish its Proceedings with those of the Societies now members thereof. Our Board had considered it, and had unanimously decided that no change in our present policy of publication was advisable, but referred the matter to the Club, that a more general expression of opinion might be obtained. The meeting sustained and endorsed the action of the Board, without a dissenting vote, and instructed the Secretary to notify the

Board of Managers of the Association of their action, and to assure them of our high appreciation of their courtesy and consideration, and of the standing and value of their publication.

A communication from the N. Y. and N. J. Branch of the International Institute for Preserving and Perfecting Anglo-Saxon Weights and Measures, requesting our assistance in promoting the objects of the Institute, was presented and laid upon the table.

Communications from the American Institute of Mining Engineers and from their Local Executive Committee, conveying their thanks to us for having availed ourselves of a portion of the pleasure conferred by their recent meeting in Philadelphia, were received and filed.

The thanks of the Club were returned to Hon. Wm. B. Smith, Mayor of Philadelphia, for the Report of the Board of Experts on Street Paving, Phila., 1884, and to Mr. John McArthur, Jr., Architect of the City Hall, Phila., for the phototypes of that building, which documents these gentlemen had kindly placed at the service of members desiring them; and, also, to Capt. S. C. McCorkle, Member of the Club, Asst. in Charge of Phila. Office of U. S. C. and G. Survey, for his considerate invitation to our members to make use of the special facilities for information, as to this branch of government work, afforded by his office.

The Secretary presented, for Mr. S. N. Stewart, a description of a Gravity Elevated Railway.

The Tellers of Election reported that the following gentlemen had been elected Active Members of the Club: Messrs. S. C. McCorkle, Edw. H. Williams, D. C. Barber, O. E. Michaelis, J. B. Hutchinson, C. R. Claghorn, Harry C. Smith, F. H. Bowen, Jr., W. B. Riegner and John Birkenbine.

Of the Board of Directors.

May 3d, 1884.—Special Meeting.—Vice President de Kinder in the chair. Messrs. Cleemann, Graff, Hering, Jones and Morris present.

The Secretary suggested that hereafter a stenographer should be employed at our meetings to preserve the discussions of papers, etc., presented. After some discussion he was authorized to try the experiment for one meeting.

It was ordered that all reprints from our publications should have printed thereon the following form of title, prepared and submitted by the Secretary:

(Title.)

by (Author) Member of the Engineers' Club of Philadelphia. Reprinted from Copyrighted Proceedings and Reference Book (or either) of the Club, by permission of the Board of Directors.

(Date.)

At the suggestion of the Secretary the Board decided that the notice, with regard to the reduction in dues to which non-resident members are entitled, placed upon the bills of the Club, is sufficient, and that members entitled to the same, and who carelessly disregard it, shall be allowed to pay full dues without comment.

The Secretary submitted the following form of application for members to use who desire extra copies of the Club Reference Book forms, and the same was adopted.

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Secretary and Treasurer of the Engineers' Club of Philadelphia.

DEAR SIR: Please furnish me with ..... cop..... of that form of the Club Reference Book containing page ..... I desire the same for my personal use and not for distribution outside of our membership.

Yours, etc.

.....

Member of the Engineers' Club of Phila.

JUNE 7TH, 1884.—Special Meeting.—President Ludlow in the chair. Present, Messrs. Cleemann, Hering, Jones and Morris.

The Secretary presented a communication from Prof. J. Burkitt Webb, Sec. of Section D of the American Association for the Advancement of Science, requesting the coöperation of the Club in the matter of their meeting in Philadelphia in September. The Secretary was directed to assure him that the Club would do its best in the premises.

A letter was presented by the Secretary from Mr. George Wright, Secretary of the Philadelphia Sketch Club, inquiring whether the Club would participate with their and other clubs, in the erection of a fire-proof building for the common use of

said clubs. He was directed to reply that the arrangements now being made by us with regard to enlarged quarters would conflict with our acceptance of the invitation.

The matter of our participation in the election of Trustees for the State College of Pennsylvania, was referred to a committee consisting of Prof. L. M. Haupt, Chn., Prof. L. H. Barnard and T. M. Cleemann.

The Secretary presented a resolution of the Boston Society of Civil Engineers, requesting the Club to join with the Association of Engineering Societies in a common publication of proceedings. He was directed, by unanimous vote of the Board, to reply that we see no reason to change our present policy in our publications.

The Secretary was directed to invite the attention of the members, in his notices for the next meeting, to the fact that the arrangements for obtaining enlarged quarters for the Club must be begun at once.

August 1st, 1884.—Special Meeting, at No. 1113 Girard Street, the proposed new Club House. President Ludlow in the chair and Messrs. Cleemann, Jones and Morris present. After inspecting these premises the Board visited the St. Stephen's Club House in the same row, where the arrangements and alterations were found to be such as would conform, in general, to our requirements. The Secretary was instructed to notify the landlord of No. 1523 Chestnut Street, that we would vacate those premises at the expiration of our lease, and to notify Mr. S. S. Cavin, Agt. Girard Estate, that we desired to lease No. 1113 Girard Street, suitably altered and renovated.

It was also decided that the application of Dr. Backus to lease from us the first floor of No. 1113, could not be granted, as it appeared that those rooms could not be spared by us.

Application having been made that cards of invitation to the rooms be issued to two gentlemen mentioned, the Board directed that in these and similar cases the personal invitation of the member should be considered sufficient.

The thanks of the Board were tendered to Gen. Huidekoper, Postmaster at Phila., for the active interest he had taken in obtaining "pound rates" for our Proceedings.

CONTRIBUTIONS TO THE LIBRARY.

FROM MAY 31ST TO NOVEMBER 17TH, 1884.

From the INSTITUTION OF CIVIL ENGINEERS, London.

Hay—Strath Taieri Bridge, New Zealand.
Witz—Gas Engines.
Burke—The Ashti Tank.
Anderson—The Delta of the Nile.
Crimp—Wandle-Valley Main Drainage.
James and Macdougall—The Canadian Pacific Railway.
Collingwood—Allegheny Suspension Bridge.
Longridge—Wire Gun Construction.
Barnaby—Hydraulic Propulsion.
Foster—The Composition of Coal.
Burge—Comparative Value of Labour.
Cowan—West Shore Railway, U. S.
Gillott—Basic Steel Process.
Rooper—Emery Wheels.
Pilkington—Shipment of Grain.
Hagemann—Transmission of Heat.
Johnson—Distilling Apparatus at Iquique.
Andrews—Galvanic Action.
Stayton—Wood Pavement in the Metropolis.
Cowan and Fawcus—A Light Draught Launch.
Bömches—The New Harbour of Trieste.
Higgin—Old Water Supply of Seville.
Trotter—A Dioptric System of Uniform Distribution of Light.
Birch—The Passage of Upland Water through a Tidal Estuary.
Apjohn—Area of Sluice Opening.
White—The Size and Inclination of Sewers.
Morton—Coaling at the Nine Elms Gas Works.
Boulton—The Antiseptic Treatment of Timber.
Brebner—Lighthouse Apparatus for Dipping Lights.
Abstracts of Papers in Foreign Transactions and Periodicals. Vol. LXXVII. 1884.

From the NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, Newcastle-upon-Tyne.

Transactions—Vol. XXXIII, Parts IV and V.

From the SOCIETY OF CIVIL ENGINEERS, Paris.

Mémoires—April May, June and July, 1884.

From L'ADMINISTRATION DES PONTS ET CHAUSSÉES, Paris.

Annales—May, June, July and August, 1884.

From the AUSTRIAN SOCIETY OF ENGINEERS AND ARCHITECTS, Vienna.

Wochenschrift.
Zeitschrift, II, III and IV–V, 1884.

From the SAXONIAN SOCIETY OF ENGINEERS AND ARCHITECTS.

Der Civilingenieur.

From the NORWEGIAN ASSOCIATION OF ENGINEERS AND ARCHITECTS, Kristiania.

Norsk Teknisk Tidsskrift, II, 2 and 3–4, 1884.

From the SWEDISH SOCIETY OF CIVIL ENGINEERS, Stockholm.

Proceedings—Första Häftet, Andra Häftet and Tredje Häftet, 1884.

From the PORTUGESE SOCIETY OF CIVIL ENGINEERS, Lisbon.

Proceedings—May-June, July-Aug., 1884.

From the ARGENTINE SCIENTIFIC SOCIETY, Buenos Aires.

Anales—April, May, June, July, Aug. and Sept., 1884.
Annuaire Statistique de la Province de Buénos-Ayres. 1883.

From the MANITOBA HISTORICAL AND SCIENTIFIC SOCIETY, Winnipeg.

Transactions—1883–4.

From the AMERICAN SOCIETY OF CIVIL ENGINEERS, New York.

Transactions—March, April, May, June, July, Aug. and Sept., 1884.

From the AMERICAN INSTITUTE OF MINING ENGINEERS, New York.

Transactions—Advance Sheets.
Index to Transactions, Vols. I to X, 1884.
Memorial of Alexander Lyman Holley. 1884. Bound.

From the AMERICAN SOCIETY OF MECHANICAL ENGINEERS, N. Y.

Transactions—Vol. V, 1884, and Index to Vols. I–V.

From the AMERICAN WATER WORKS ASSOCIATION, Hannibal, Ohio.

Rep. of 4th Annual Meeting—1884.

From the AMERICAN IRON AND STEEL ASSOCIATION, Philadelphia.

The Bulletin.
An. Rep. of Secretary—1884.
The Iron and Steel Works of the U. S. 1884. Bound.

From the UNITED STATES ASSOCIATION OF CHARCOAL IRON WORKERS, Phila.

Journal—June, Aug. and Oct., 1884.

From the AMERICAN SHIPMASTERS' ASSOCIATION, New York.

Record of American and Foreign Shipping—Nos. 6, 7, 8, 9 and 11, 1884.

From the ASSOCIATION OF ENGINEERING SOCIETIES, New York.

Journal—June, July, Aug., Sept. and Oct., 1884.
" —Vols. I and II, bound; Vol. III, Nos. 1 to 9 inclusive.

From the WESTERN SOCIETY OF ENGINEERS, Chicago.

Proceedings—Abstracts.

From the ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA, Pittsburgh.

Transactions—Advance Sheets.

From the AMERICAN PHILOSOPHICAL SOCIETY, Philadelphia.

Proceedings—Vol. XX, No. 111, and Vol. XXI, No. 115.

From the PHILADELPHIA SOCIAL SCIENCE ASSOCIATION.

Du Puy—A Plea for Better Distribution. June 17th, 1884.

From the BOSTON PUBLIC LIBRARY.

32d An. Rep. of Trustees—1884.

Bulletin—Autumn, 1884.

From the LIBRARY COMPANY OF PHILADELPHIA.

Bulletin for July, 1884.

From the FRANKLIN INSTITUTE, Phila.

Journal—June, July, Aug., Sept., Oct. and Nov., 1884.

From the ENGINEER DEPARTMENT, U.S.A., Washington, D. C.

An. Rep. of Chief of Engineers, 1883. Parts I, II and III. Bound.

Maguire—Professional Notes. 1884.

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CHANGES IN LIST OF MEMBERS.

Active.

Additions May 17th, 1884.

Converse, John H., Baldwin Locomotive Works,
500 N. Broad St., Philada.
Sayen, W. Henry, Consulting Mech. Engr.,
107 S. Eighth St., Philada.
De Haven, I. Norris, Foreman Wm. Sellers & Co.,
527 S. Forty-second St., Philada.
Megear, Alter, Civil Engr., 3306 Arch St., Philada.
Howell, Benj. P., Engr. of Mines, H. C. Frick Coke Co.,
Scottdale, Pa.
Matsdaira, T. A. M., City Engr., Bradford, Pa.
Davenport, R. W., Supt. Midvale Steel Co., Nicetown, Philada.
Pott, John N., Civil and Mining Engr., Pottsville, Pa.
Wilson, J. B., Iron, 209 S. Third St., Philada.
Brooke, Walter C., Mineral R. R. and Min. Co.,
Shamokin, Northumberland Co., Pa.
Cabot, W. Brooks, Engr. Everett Iron Co.,
Everett, Bedford Co., Pa.
Thompson, Gaylord, Res. Engr. S. P. R. R.,
Everett, Bedford Co., Pa.
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Additions June 21st, 1884.

Coxe, Eckley B., Mining Engr., Drifton, Luzerne Co., Pa.
Robinson, Wm. H., Mech. Engr., Baldwin Loco. Works,
2118 Park Ave., Philada.
Holliday, Robt. L., Supt. Bedford Div. P. R. R.,
Bedford, Bedford Co., Pa.
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P. O. Box 655, Altoona, Pa.
Wood, James F., Mech. Engr. and Contractor,
12th and Thompson Sts., Philada.
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Stewart, S. N., Mech. Engr., 3041 Dauphin St., Phila.

Faunt Le Roy, A. R. Asst. Engr. C., M. and St. P. Ry.,
Milwaukee, Wis.
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4001 Sansom St., Philada.
Brown, T. Benton, Asst. Engr. L. V. R. R., Mauch Chunk, Pa.
Sanne, Oscar, Civil Engr., Edge Moor Iron Co., Wilmington Del.
Dechant, Wm. H., Div. Roadmaster, P. & R. R. R.,
Tamaqua, Schuylkill Co., Pa.
Heuer, W. H., Maj. of Engrs. U. S. A., 1125 Girard St., Philada.

Additions October 4th, 1884.

McCorkle, S. C., Asst. U. S. C. and G. Survey,
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33d and Arch Sts., Philada.
Barber, D. C., Civil and Sanitary Engr., Philada. Water Dept.,
Box 505 P. O., Philada.
Michaelis, O. E., Capt. of Ordnance, U. S. A.,
Frankford Arsenal, Philada.
Hutchinson, J. B., Supt. Frederic Div. P. R. R.,
York, Pa.
Claghorn, C. R., Asst. Second Geol. Survey of Penna.,
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Box 4, Media, Pa.
Bowen, F. H., Jr., Asst. Engr. P. & R. R. R.,
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413 Walnut St., Philada.
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152 S. Fourth St., Philada.

Additions November 1st, 1884.

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Pottsville, Pa.
Hill, Frank A., Asst. Second Geol. Survey of Penna.,
P. O. Box 501, Scranton, Pa.
Bache, R. Meade, Asst. U. S. C. and G. Survey,
P. O. Building, 9th and Chestnut Sts., Philada.
Forder, Emil, Civil Engineer,
Revere House, Denver, Col.
Coxe, W. E. C., Pres. Montour Iron and Steel Co.,
Reading, Pa.
Pistor, Philip, Mech. Engr., Warden & Mitchell,
2127 N. Twelfth St., Philada.

Harden, O. B., Asst. Second Geol. Survey of Penna.,
907 Walnut St., Philada.
Loomis, Thos. H., Asst. Engr. S. P. R. R.,
Harrisburg, Pa.
Hoopes, Barton, Jr., Hoopes & Townsend,
1330 Buttonwood St., Philada.
Biddle, Wm. F., Civil and Mining Engr.,
209 S. Third St., Philada.
Winston, Lindley M., Civil Engineer,
139 W. Penn St., Germantown, Philada.
Sanborn, H. W., Asst. Engr. Philada. Water Dept.,
13th and Spring Garden Sts., Philada.
McComb, S. Craige, Asst. Supervisor P. R. R.,
Tacony, Philada.
McCallum, Wm. H., Mech. Engr., New Glen Echo Mills,
Wayne Junction, Philada.
Wiley, Wm. H., Civil Engineer,
15 Astor Place, N. Y. City.

Additions December 6th, 1884.

Turner, George, Jr., Mech. Engr. Siemens Reg. Gas Lamp Co.,
N. E. cor. 21st and Washington Ave., Philada.
Newhall, George M., Genl. Mgr. Philada. Sugar Refinery,
225 Church St., Philada.
Townsend, Edw. Y., Pres. Cambria Iron Co.,
218 S. Fourth St., Philada.
Drinker, Henry S., Mining Engineer,
218 S. Fourth St., Philada.
Sargent, F. W., Asst. Engr. of Tests, C. B. & Q. R. R.,
P. O. Box 1962, Aurora, Ill.
Beatty, James, Jr., Prof. of Engineering,
Haverford College, Pa.
Evans, Richard, Asst. Engr. Philada. Survey Dept.,
1633 S. Broad St., Philada.
Feldmann, Max B., Mech. Engr., Penna. Globe Gas Light Co.,
617 Arch St., Philada.
Moore, C. Frederick, Civil Engineer,
1507 Fairmount Ave., Philada.
Elliott, John S., Instructor in Civil Engineering,
Univ. of Penna., 34th and Locust Sts., Philada.
Hunt, Conway B., Asst. Engr. P. R. R.,
Room 7, Union Station, Pittsburgh, Pa.
Hoffman, John R., Asst. Min. Engr., P. & R. C. & I. Co.,
622 Mahantongo St., Pottsville, Pa.
Mullen, John, Mgr. and Propr. Shamokin Iron Works,
Shamokin, Northumberland Co., Pa.

WETHERILL, ROBT., Engine Builder,
Chester, Pa.
PHILIPS, FERDINAND, Supt. Engr. Hoopes & Townsend,
1330 Buttonwood St., Philada.
BERGNER, THEODORE, Mechanical Engineer,
424 Walnut St., Philada.

Resignations, etc.

R. M. BARTLEMAN.
DAVID PEELOR.
WM. W. PERKINS.

BOOK NOTICES.

A TEXT BOOK ON THE METHOD OF LEAST SQUARES, by Mansfield Merriman. New York, John Wiley & Sons, 1884.

In the present days of active construction, when works of surpassing magnitude are being built, and the saving of a few pounds of material may turn what would be a failure into a success, engineers are careful to note their experiences, and correct their formulas by their results. In doing this they often use some method of guessing at the most probable way of using their experiments in finding a rule or law. That there is a rational way to accomplish this, it is the object of this book to show. As an example of its contents, it may be mentioned that it gives the method of balancing the errors in observing the angles in a series of triangles; in measuring a base line several times; in several series of levels between places; the method of finding empirical formulas to represent the results of experiments, and, having found the formula, to find the most probable values of the constants in it to suit the experiments.

The problems and queries at the ends of the chapters are admirably selected, and a solution of them is, in fact, the only way in which the conscientious student can satisfy himself that he perfectly understands what has gone before.

The deductions of the law of error according to the methods of both Hagen and Gauss, will no doubt be difficult for some to follow, and probably the first may seem the simpler to many. Perhaps the abstruseness of the subject may make it impossible

to deduce the equation of the probability curve in a simpler way. As, however, the method of limits is more satisfactory to the metaphysician in explaining the fundamental principle of the differential calculus, rather than that of neglecting differentials of the higher orders, we prefer the method of Gauss.

We congratulate the author on the almost absolute freedom from typographical errors, which are so usual in a work of this kind. We have only noticed the following, which we submit for his consideration: On page 29, last line, a sign of infinity should be moved around; on page 32, in the table, in the first line, for 2 read 1; on page 47, in the equation in the middle of the page, for b^2 read $a_2{}^2$; on page 106, line 2 from the bottom, for 38 read 37; on this and the following pages the sign of equality seems to be left out of the equations; on page 162, in first line of second paragraph, for "Chap. III," read "Chap. II"; on page 163, line 5 from bottom, for 933 read 993.

Wrought Iron and Steel in Construction. New York, John Wiley & Sons, 1884.

The constructing engineer finds himself in constant need of consulting trade catalogues, so that he may know what the market furnishes that would best suit his purpose. The latest of these for workers in wrought iron and steel, is that of the Pencoyd Iron Works, Messrs. A. & P. Roberts & Co., of Philadelphia. It is of convenient shape, and has the various sections made by the firm figured on pages at the end, so that a reference is much more handy than to consult an unwieldy sheet such as manufacturers usually offer to their customers. A flexible leather back and gilt edges add to the attractiveness of the book, but do not detract from its matter, which, unlike many subscription books, does not exhibit all its merit on the outside. The tables of dimensions and weights of I beams, channels, deck beams, angles and tees are very complete, and are made much more valuable by having radii of gyration calculated for each one. Now, when Rankine's formula is the accepted one for the strength of columns, it is a great facility to have the least radius of gyration already calculated, and this book goes further than other works of its class in giving methods of calculating this least radius for many of the built shapes that are ordinarily used in construction.

PHOTOTYPE F. GUTEKUNST PHILAD.A

William Ludlow

PRESIDENT DURING THE SEVENTH YEAR OF THE CLUB, A. D. 1884.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17th, 1877.

NOTE.—The Club, as a body, is not responsible for the facts and opinions advanced in its publications.

Vol. IV.] FEBRUARY, 1885. [No. 5.

ANNUAL ADDRESS

OF COL. WILLIAM LUDLOW, Retiring President.

Read January 10th, 1885.

FELLOW MEMBERS AND GENTLEMEN: It is perhaps the most marked and characteristic feature of the progress of modern civilization, that the ties which unite the nations of the world, and are so rapidly weaving the web of a universal brotherhood, year by year become more numerous and more diversified, and are reaching out further and still further to the confines of the globe. Could an ancient philosopher be roused from his sleep of ages and recalled to participation in the life of to-day, nothing, I think, would so startle his awakened intelligence and so fill his soul with amaze, as the marvelous celerity and accuracy with which, each day, the events of the world are brought to our apprehension, and the occurrences at every centre of human activity are gathered and recorded for our information and study. He would see mankind, like the gnomes of fairy-land, toiling in every corner of the earth with an incredible energy and a persistence forbidding discouragement; delving the earth, digging canals, building railways, constructing bridges and tunnels, laying telegraph lines, navigating great ships, rearing huge structures, covering the

world with the products of their industry and changing the face of Nature.

Studying more closely the methods of this ceaseless activity, he would presently discern that it was all regulated and directed by the faithful and intelligent observance of natural laws, some of which he would recognize as familiar to him, while others would be mysterious and unintelligible. But, however he might marvel at the strange and mighty forces tamed by man into docile and useful servants, he would recognize that Knowledge was the power which enabled him to rule them, and Science his most efficient coadjutor and faithful friend.

The domain of Natural Science may be broadly divided into the fields of Investigation and Application, and the workers in these respective fields are the Physicists and the Engineers. It is true that no fixed line of demarcation can be drawn between them, and the borders of each are constantly passed and re-passed by throngs of laborers from the other; but in the general view the Engineer is he who impresses into his service and utilizes for the construction of works useful to mankind, all the forces of Nature of whatsoever sort he may find most applicable to the work in hand, and the more thorough his knowledge and the severer his scientific training and industry, the greater master is he of his profession, and the more capable of accomplishing those monuments of practical endeavor which have placed him in the front rank of the benefactors of the world.

As must always be the case when huge stores of knowledge accumulate, the limitations of our lives and abilities forbid an equal familiarity with them all, and whether by force of circumstance or personal predilection, we are guided in certain directions in which our activities and endeavors are most exerted and displayed. It follows that a certain dividing up of industry is effected, whereby each presses in his own course, and the general bounds of knowledge and experience are enlarged in all directions, as an elastic envelope is expanded by the multitudinous energies of the moving atoms within. While this differentiation of industry is favorable to the general progress, as well as to the best development of the capabilities of the individual worker, it is incumbent upon him to see that in the strenuous application

of his effort in the particular direction which he adopts, he shall not lose sight of the advantage of at least a partial familiarity with the advances made and the new ground acquired in other directions, lest thereby he be deprived of the assistance of which at almost every point he must avail himself, if the maximum of success is to be attained.

Thus, too, for the student preparing to embark upon the active exercise of his profession in responsible work—let him see to it that before starting out upon the special branch to which he proposes to devote himself, he shall be thoroughly grounded in fundamental principles, and thereafter not omit to keep himself familiar, by careful reading and study at least, with the progress of science in other lines than his own.

Another duty of the Engineer, and one to which too little heed is paid, as I conceive, is the omission or neglect to record in some form, the experience which is daily accumulated in active work; whereby not only the individual himself may suffer from the absence of needed information at a critical time, but the profession at large is deprived of the advantage of knowing a thousand things, great and small, for which useful applications would be found. In this respect it may be said that failures, when intelligently recorded, are even more instructive than successes, as the beacon, warning of the vicinity of the sunken wreck and indicating a needful change of course, often gives more useful information than the sounding lead, which says "no bottom," and may betray the navigator into overconfidence when most in need of caution.

Organizations like our own may be made of the greatest utility, both to their own members and the profession generally, if those who are engaged in active work or investigation, will consider it a duty to record and communicate, in the form of contributions, detailed accounts of their labor, and note the many points of interest and value which are constantly occurring in the diversified branches of industry which they represent.

In looking back over the history of the world, and considering its gradual emergence from the mysticism and sombre shades of an age of comparative ignorance, it is readily perceived that the rapid progress made, and in particular the great leaps by which

from time to time civilization has advanced, can be traced in nearly every instance to the discovery or development of a natural law and its application to practical work. The printing press, the steam engine and the telegraph, have been the great factors in the development of the favorable conditions of modern existence, and have made possible that accumulation and dissemination of knowledge which enable man, by the power of thought, to contend with and overcome the rude inertia of opposing elements. From generation to generation he has snatched new and more potent weapons from the arsenal of Nature for his maintenance and advantage. In the dim past he dwelt in a cave and slew his prey or his enemy with a club broken from a tree; then made of it fire for nourishment and warmth. Later, his weapon became a lever, and he learned to build. He spread his robe to the wind and became a navigator; found metals and learned to shape them into tools; domesticated the brute creation for food and service; planted seed, and made a windmill grind his corn; launched vessels and traded with foreign countries. With every succeeding age progress became more rapid, and with enlargement of knowledge and experience came expansion of intelligence and development of the power of reasoning, until to-day steam is his daily servant, electricity his habitual messenger, and man is indeed the master of the earth.

What may be the developments of the future it is vain to anticipate:

> "Yet I doubt not through the ages one increasing purpose runs,
> And the thoughts of men are widen'd with the process of the suns."
>
> "Men my brothers, men the workers, ever reaping something new,
> That which they have done but earnest of the things that they shall do."

It may well be that there are latent in the universe, other forces which to-day we are unconscious of, or suspect merely. As the expansive energy of steam succeeded the visible motor powers of wind and water, and as the still subtler element of electricity (the full utilization of which opens up a vast field of possibilities) took its station in the practical service of mankind, so may there be other forces still more mysterious and potent.

It must be observed, however, that every new manifestation of

force—however ignorant we may be of its real nature—ranges itself within the jurisdiction of known laws controlling the universe, and there is no room for that presumption of charlatanry that would seek to falsify the laws of Nature and mystify the mind with miracles.

The engineering history of the past year proves it to have been one of great activity, less marked perhaps by the actual completion or inauguration of great projects than with the progress made and the new ground secured in numerous fields.

In considering these it is apparent that canal projects continue to occupy the position of greatest prominence. Large expenditures have been made and considerable work done in connection with the Panama Canal, under the direction of M. de Lesseps and the French Company. As to the actual results attained and to be anticipated there is much diversity, not only of opinion but of reported facts, and it cannot be denied that the general drift of the evidence is unfavorable to the completion of the work within the estimated time and cost, and indicates that the enormous physical difficulties attending its construction were neither fully anticipated nor adequately provided for in the estimates.

These great works, however, when once fully established, sometimes go forward, as it were, of their own inertia, and it is possible that notwithstanding the immense expenditure that will ultimately be found necessary in the case of the Panama Canal, means will be found to complete it.

The Nicaragua project has received fresh impetus from the preliminary negotiations of a treaty between the Government of that Republic and our own, which contemplates the assumption by the United States of the charge of the undertaking in return for certain concessions—pecuniary, political and territorial.

As in all similar enterprises, much diversity of opinion is expressed both as to cost and relative advantages. As compared with the Panama project, objection is made to the use of locks instead of an open channel, on account of the probable obstruction to traffic and possible inadequacy of lockage. Experience with works of this kind, however, tends to show that neither in dimensions of locks, height of lift nor reduction of time required to pass a vessel, has the limit of possibility yet been attained.

The St. Mary's Falls Canal lock built by the United States is 515 feet long and 80 feet wide, with a lift of 18 feet, and the time required to pass a ship is 17 minutes. There is no reason to suppose that the lift could not be made much greater without any necessary addition to the time of transit.

The cost of the Nicaragua project, as originally planned, was considerably in excess of $100,000,000, but more careful computations and judicious changes of location have reduced this, and the current estimates now vary between fifty and sixty-five millions. The international and political complications surrounding the project may defer or defeat its inauguration, but it seems probable that could it be begun, it might be completed before the Panama Canal could be made ready for traffic.

The Tehuantepec Ship Railway project naturally takes its place with the mention of the Isthmian Canals. The bill heretofore presented to Congress making provision for Government aid, by extension of credit, has been temporarily withdrawn by the projectors on account of the expiration of some conceded privileges and the desirability of making certain modifications of plan. It may be anticipated, however, that the versatile and ingenious author of the project will not willingly see his labor already expended lost, and that the scheme will be revived at a later day.

The Isthmus of Corinth Canal, upon which work began in 1882, and which it is anticipated will be opened for traffic in 1886, is but the final phase of a project considered some centuries before the Christian Era, and actually begun by Julius Cæsar. It has a length of less than four miles, with a cross-section the same as that of the Suez Canal.

The Manchester Ship Canal, designed to afford that thriving and ambitious town the advantages of a seaport, after two years of parliamentary discussion and argument, involving the expenditure of an immense sum in the preparation of plans and the evidence of expert witnesses, has at last been rejected by the committee. It was devised for the heaviest ocean traffic, with locks 550 feet long and 60 feet wide. The total cost of canal and locks would be $27,000,000, and including the construction of the works in the estuary, $34,000,000. It was by reason of this

last feature that the Committee finally condemned the project, mainly upon the evidence of Capt. Eads that the proposed training walls were projected upon erroneous principles, and would injure the navigation of the estuary.

The St. Petersburg Maritime Canal, opened for traffic in October, has a total length of 17¾ miles. The construction was almost entirely by dredging, and occupied six years in completion, at a cost of $8,000,000 for a 24½ feet navigation.

At home the several canal projects—of which the chief are the Hennepin and the Delaware and Chesapeake—have not made much advance beyond the preliminary surveys and discussion. Both look to the United States Government for means of completion.

The Erie Canal, to which so much of the past and present prosperity of New York is due, is gradually (under State management) failing to meet the requirements of transportation, and the State Engineer has recently spoken rather hopelessly of its future usefulness. It is important to remember, however, that while water-ways, whether natural or artificial, cannot compete with railways for rapid traffic, and while therefore only the freights whose bulk is disproportionate to their value and which may without injury await the slower means of delivery at their destination, will, as a rule, seek the cheaper means of transportation, the true function of the canal is to act as a conservator of trade and regulator of rail charges. In this regard the utility of maintaining and enlarging the capacity of Erie Canal is manifest, whether as a competitor of the roads, or of the great Canadian freight routes which our British neighbors are earnestly seeking to develop.

In tunnels, since the completion of the Arlberg, where the favorable action of the Brandt system of boring in hard rock by the use of hydraulic high pressures was illustrated, the leading feature has been the tunnel under the Severn, which is now reported as rapidly nearing completion. The work was begun in 1873, and the difficulties encountered—mainly from the inbreaks of water in uncontrollable quantities—have been enormous. The tunnel has a total length of 4½ miles, half of which lies under the Severn.

Railway construction in 1884, has, in this country, fallen very far short of the extension of former years, and a corresponding depression has been quite general in the industries which look largely to this branch of engineering for support.

In other countries greater activity has been shown. In India the recurrence of extensive and disastrous famines among a population three-fourths of which are engaged in agriculture and are without means of intercommunication, has led to the advocacy of a project for the construction of about 5,000 miles of road during four consecutive years, at an estimated average cost of $30,000 per mile.

In France the projects now adopted—and partly completed—involved the expenditure in the years 1884 and 1885, of between thirty-five and forty millions of dollars, about equally divided between the State and private companies.

The immense output and low cost of the petroleum product in the Caspian region of Russia, have developed the use of this as a fuel both for steamers and locomotives. It is calculated that one ton of petroleum is equivalent in steam-making capacity to three tons of coal, with many advantages in the direction of absence of ash and smoke, and facility of taking in supplies.

It is worth consideration with us whether this fuel, though less cheap than the Russian product, might not be used to advantage at least on our fast passenger expresses, since the construction of locomotives has so far advanced that greater sustained speeds apparently are only practicable by the use of higher pressures and a more rapid evaporation.

On our continent, the extension of the Canadian Pacific is of great interest, since it is designed as a formidable rival of our own lines. When completed, the distance from Yokohama to Liverpool via the Canadian Pacific will be at least 1,000 miles less than via the Central Pacific.

In bridge construction the great Forth viaduct occupies the most prominent position, and the detailed reports of the engineers are full of information and instruction. The contract was let in December, 1882, at a cost of $18,000,000, and operations were begun in the following month. The construction of the work involves the placing of 120,000 tons of masonry and 45,000 tons of steel.

The success of the Niagara Cantilever has led to further similar projects. The Canadian Pacific has adopted it for the passage of the Frazer River, and a cantilever design for the crossing of the Harlem Railroad in New York has been prepared and submitted by our fellow-member, Mr. Joseph M. Wilson. A great railroad bridge is also proposed across the St. Lawrence at Quebec.

The new Atlantic Cable, known as the Bennett-Mackay, was successfully landed at Coney Island in October last, and is in use, to the great advantage of its patrons.

A Northern Cable has been projected, which, starting from the coast of Scotland, is to extend thence to Gaspé Harbor on this side, via the Faroe Islands, Iceland, Greenland and Lawrence Bay. The total length of wire is 3,150 miles, but the longest submerged section will be 900 miles only, with corresponding great anticipated advantage over other cables.

America is easily in the lead of all other countries in the practical and extensive application of electricity to daily business uses, and the department of electrical engineering is steadily assuming greater importance.

In England and Europe the extravagant and speculative formation of companies for electric lighting has had the effect to retard the real development by the making of heavy losses and the forfeiture of public confidence, but in the end the lost ground will no doubt be regained. As oil replaced tallow, and gas oil, so must the pure, cool and grateful glow of the electric light become the light of the future, as well (and better) for the illumination of our houses as for the lighting of our streets and large areas. In fact, sanitary engineering will eventually insist upon its adoption in dwellings, since the consumption of oil and gas not only exhausts a portion of the oxygen of the air we breathe, but vitiates the remainder by the products of combustion. The incomparable advantages of electricity in this regard, as well as the comparative immunity from danger of fire, must force it into general use, and means will be found to cheapen it, so that it shall be within the reach of all.

The telephone assumed at once its place as an indispensable element of city life, and the practical development of its usefulness has immensely increased. Conversation has been sustained

easily over distances largely exceeding 1,000 miles, and the limits of this application of electricity have not by any means been reached.

In telegraphy a notable advance has been made by the Delany synchronous multiplex system, by means of which the almost incredible result has been attained of transmitting simultaneously six separate and distinct messages, at the rate of 40 words per minute, over a single No. 6 galvanized iron wire, or 12 different messages at the rate of 20 words per minute each. This has been actually accomplished between Boston and Providence, 50 miles apart, with a return wire, making the entire distance traversed by the separate messages over 100 miles. Railway telegraphing has also been effected by using the wire of the railroad fence; and a novel and successful method of fishing has been tried by using a submerged arc light of 15,000 candle power.

The multiplication of wires in cities for telegraph, telephone and lighting purposes, is attended with such serious inconveniences—and in some cases danger—that strenuous efforts have been made to get the wires underground. The several companies admit the desirability of this, but object to the expense, and argue that no satisfactory system of underground wiring has yet been established. It appears, however, that these arguments cannot be accepted as conclusive, since underground telegraphy has been practiced in France since 1880, and there are now over 2,500 miles of underground wire in use.

Elaborate and costly experiments on a large scale in the transmission of power by electricity, have also been making near Paris over 70 miles of cable—with results not yet recorded. This branch of electrical engineering is still in its infancy.

Two ingenious and enterprising French captains have succeeded, by aid of an electric motor, in navigating the air for a journey of several miles, making a circuit and returning to the starting point. The air ship was under very good control, and the steering apparatus operated effectively. It is considered that with moderate movement of the winds—say 10 to 15 miles per hour—air navigation has been shown to be practicable.

Steam engineering is a history of continued progress. Some of the fastest Atlantic passages on record have been made during

the year, and the duration of the trip has been diminished until several vessels have accomplished it in a little over 6 days. The latest example of high art in steamer construction is the Umbria, of the Cunard Line, which, with the exception of the Great Eastern, is the largest vessel ever built. Her length is 520 feet, breadth 57 feet 3 inches, depth 41 feet, and tonnage 8,000. She has 9 cylindrical steel boilers, each having 8 Fox's corrugated furnaces, or 72 in all, with a heating surface of 38,500 square feet. The 3 cylinder engines developed 13,500 horse power, and the ship showed on her trial trip the wonderful speed of 21 knots, or 24⅕ miles per hour.

Coal consumption has been economized until now with 110 to 150 lbs. of initial pressure, the combustion of 1.3 to 2 lbs. only is required per horse power per hour.

The opening up to steam navigation of the two great rivers of Africa, the Nile and the Congo, are points of exceeding interest. Whereas the Dark Continent, notwithstanding that it has been the seat of some of the most ancient civilizations of which we have knowledge, has failed to maintain its former supremacy, and alone of all the great territorial divisions is occupied almost exclusively by semi-civilized and barbarous people, at the present time its development has attracted marked attention, and it is probable that, attacked from all directions, the conquest and enlightenment of this vast empire will exhibit a rapidity of movement unexampled in history.

The new steel cruisers for the U. S. Navy have occasioned sharp criticism, which, however, has not delayed their construction. The "Chicago," of 4,000 tons, is half finished. The "Atlanta," 3,000 tons, is launched and the machinery is going in. The "Boston," 3,000 tons, is ready to leave the ways, and the despatch boat "Dolphin," 1,500 tons, is ready for sea. The critics have attacked both the type and motive power of these vessels, which exhibit many features novel in war vessels; but since the test of their capabilities can shortly be made, further comment may properly be postponed.

It would seem, however, in comparison with the 18 and 20 knots speed of English constructions, that the maximum of 14½ and 15 knots estimated for the American cruisers is little enough to enable them either to capture or escape a hostile vessel.

The subject of military engineering, as exemplified in the construction of guns and armor, here suggests itself, especially as the National Legislature has apparently been at last aroused to a consideration of the fact that in both respects is the nation not only defenceless, but actually incapable of defence, by reason of the total absence both of guns and armor and of the plant requisite for their construction.

It is obvious that this condition of affairs is incompatible with the dignity and position of the United States as a power of the first class, and that unless all the teachings of history are to be disregarded, the construction and maintenance of national defences for our great seaboard commercial centres, at least, are indispensable, if at some future time national humiliation and enormous losses are to be avoided.

Since the appliances of war are only used by Governments, and as their construction involves a plant adapted to the production and manipulation of refined metal in masses vastly greater than are required for ordinary purposes, it is manifest that no private firms can undertake such work unless the expense of erecting and operating the extraordinary plant required is provided for. Government appropriations are therefore indispensable, and the choice lies between the investment of funds from the Treasury in the establishment of national foundries and gun shops, or in the making of contracts with private firms of sufficient magnitude and duration to warrant them in assembling such expensive plant. This matter is now under consideration by the Federal authorities. Of armor protection for vessels and land defence there are four principal types, viz.: wrought iron plates, compound plates of iron with steel faces—the two flowed together at welding heats and intimately united, plates of solid steel and massive shields of chilled cast iron. Opposed to these are the mighty English weapons, the 80 and 100 tons guns, and those of Krupp's manufacture, rivaling them in power. In the construction of these tremendous weapons, steel is the metal employed, and its manufacture and preparation call for the display of the most advanced metallurgical art.

Much is expected from the use of steel wire wrapped about a central longitudinal steel core, the wire being put on under a

carefully computed and adjusted initial tension. Guns can be made in this way to withstand a pressure of 33 tons per square inch. A 6-inch wire gun of American steel is now under construction at the Washington Navy Yard. The Haskell Multicharge Gun has been preliminarily tested at the Government proving ground at Sandy Hook, with good results. The principle is that of an initial charge followed by the successive explosion of additional charges stored in pockets beneath the gun, and discharging behind the shot. By this means the pressure is fully maintained while the shot is in the bore, and in consequence the velocity with which the projectile is finally impelled is greatly increased, adding to the extent and accuracy of its range and its destructive effect.

A gun operated by compressed air, for throwing a shell containing a charge of dynamite, has been tested at Fort Hamilton, N. Y. Harbor. The gun is in the form of a tube of 4-inch bore, and forty feet in length. With air compressed to 500 lbs. to the square inch, the projectile, four feet long and weighing 18 to 25 lbs., was readily thrown across the Narrows, a distance of a mile.

Aside from international considerations, the intimate connection of our own industrial interests with the production and development of ships, turrets, armored casemates, revolving forts, cannon, and all the appliances of modern warfare, is sufficiently manifest, and the subject claims attention if only upon this ground.

To the great subject of River and Harbor Improvement, involving the application of the best hydraulic engineering, but brief reference can be made.

These great works are carried on under the immediate direction of Congress, and by aid of National appropriations. The United States have the most magnificent system of internal waterways of any country in the world, and the traffic upon them transcends in value that of all our foreign commerce many times over. No system of transportation has yet been discovered at once so convenient and economical as the utilization for navigable purposes of our inland lakes and rivers, and the National Government, recognizing this fact, and mindful both of the importance of conserving so vital a feature of our national prosperity and the im-

practicability of entrusting the responsibility to communities or companies, has undertaken the great task of its development. Chief among these is now the regulation of the Mississippi River, the most formidable problem in hydraulic engineering ever presented for solution. To all intents and purposes the Mississippi and Missouri are one, and we have therefore the conditions of a stream traversing the entire breadth of the country, from north to south, which at nearly every point of its course flows in an alluvial bed, and through an alluvial valley to a great extent constructed by itself out of materials transported from higher points. The tremendous volume of the stream, its mighty floods, raising the surface forty feet and more, and submerging hundreds of square miles of the most fertile land on the globe, the enormous freight of sediment carried in suspension and swept along its bed, its waywardness and scorn of control, its constant change of channel and the extraordinary havoc wrought thereby in bordering lands, all combine to impart to the river the attributes of a majestic and lawless individuality which might well intimidate the boldest Engineer.

It is manifest that no power on earth would suffice for the regulation of such a stream, unless it can itself be tamed to do the work. The Mississippi River Commission is proceeding upon this thought, and step by step is seeking to induce the river itself to forge its own bonds and build its own prison. A definite width adjusted to the flow of the stream, with a suitable depth to pass its volume and conform to navigable requirements, has been determined upon. Where, from undue expanse of surface the depth is inadequate, light constructions of weeds, of willow or piling, with woven meshes, are placed, and the River deposits thereat its superfluous load of sediment by the thousands of cubic yards, and proceeds to scour its proper channel. Where the banks are caving and it is needful to retain them, willow mattrasses are laid and covered with stone, and the river sweeps by without injury.

The work is manifestly one of immense magnitude, and years will be required for its completion. In fact it will ultimately be necessary to operate throughout the entire length of the stream. Comparatively little of the material constantly eroded from its banks and reaching the channel, ever makes its escape into the

Gulf. As a consequence the bed is constantly rising, and unless this tendency be checked, the height of the restraining levees must forever be increased. To prevent this, the bank protection must be thoroughly effected wherever necessary, and the Missouri in this connection must be included.

Enormous as must no doubt be the ultimate expenditures, the interests at stake in the immense and fertile valley of the Mississippi are comparable thereto, and it is probable therefore that the work which has been inaugurated will be continued.

The tidal harbors, too, of our sandy coast require attention, from the inadequacy of depth upon their bars for free and safe admittance of shipping. Among the most important of these in progress are the harbors of Galveston and Charleston, where the effect of training walls directing the outflow across the bar in a constant direction, are relied upon to create and maintain a favorable depth. Great complaint is made of the shoaling of the New York Bar, and the consequent injury to the commerce of this most important centre of trade. The available depth has decreased from 25 to 23 feet, and the demand of modern ship building is for a depth of 30 feet. Arriving vessels, lightened by the consumption of coal during the voyage, are less inconvenienced, but the departing ship is compelled to leave hundreds of tons of valuable freight upon the wharves. The attention of Congress has been drawn to this important point, and it is probable that consideration will be given to the means of amending so serious a detriment to our commercial facilities.

Harbors of refuge are needed at several points of our coast, notably between New York Bay and the Delaware Capes, and between those and Hampton Roads. The Pacific coast is singularly destitute of harbors—the Golden Gate being the only one of adequate extent and facilities. Provision will undoubtedly be made for these in course of time by the general Government.

It is a marked illustration of the law of supply and demand that the advantages of steel over iron for certain purposes, its superior strength and endurance, and greater homogeneousness of structure, have so developed the manufacture of this useful metal, that the discovery and perfecting of the processes for producing it have cheapened its cost until it has challenged its competitor in the markets even for uses hitherto unforeseen.

The Bessemer processes were the first great step in this direction, and the later discovery that a good quality of steel could be manufactured directly from comparatively inferior ores, hitherto considered unsuited to the purpose, completed the work.

A novel method of making plates by the aid of centrifugal force has been recently tried with good results. A horizontal cylinder with a central feed of molten steel is revolved, and a hollow cylinder formed of any desired thickness. The inner cylinder is drawn while hot, sawed longitudinally and re-rolled.

A marked feature of the iron industry has been the production and marketing of nearly 100,000 tons of pig from Southern furnaces. The metal, though inferior to that of Northern make, is still of so low cost as to affect the market. This, in combination with a general dulness of trade, has kept the iron producing industry in a depressed condition throughout the year.

Pennsylvania, already so favored as the great treasury of coal, iron and petroleum, has added to her existing sources of wealth another, which bids fair to be of great future importance and value, in undertaking the utilization, on a large scale, of her vast stores of natural gases, especially those adapted to heating and manufacturing purposes. The most advantageous methods of manipulation are still the subject of experiment and practical test, but the convenience and economic value of the natural product, and the practicability of its delivery in pipes at considerable distances from the flowing wells, are not disputed, and the business of supplying it will undoubtedly become one of great importance.

Sanitary Engineering has greatly developed in this country during the past few years as an independent specialty, mainly owing to the increased consideration given to sanitary matters, the growth of public feeling in consequence of increased knowledge of the importance of good sanitation, and the necessity—particularly in centres of population—of the amendment of existing evils and abuses inherited from the ignorance and imperfect constructions of the past, and continued to the present with more and more obviously evil influence upon the public health.

The construction of the great sewage works of London, and the marked attention subsequently given to their effect, have stimu-

lated in other cities the investigation of sanitary principles. In particular the successful completion of the Boston sewerage system, by which all the fluid waste matters of the city are collected in intercepting sewers, conducted to Moon Island, in the harbor, and thence discharged at the first of the ebb and sent to sea, has led in numerous other American cities to the consideration of plans for sewage disposal. The subject is a very broad and weighty one, that cannot be more than referred to in a paper of this kind. The conditions vary with every locality, and the closest observance of principles must be combined with accurate knowledge and study of local requirements.

The London sewage is discharged into the Thames below the city, and great complaint has been made of the accumulation in the river bed of foul material and the evolution of sickening odors and deleterious gases. The extension of the outfall to the sea is under discussion, as well as the precipitation and partial purification of the sewage.

In the case of cities which have not a great river to receive the waste, the plan of surface irrigation has been tried, and the conditions being favorable, with good results. In this respect the Dantzig sewerage is a conspicuous example of the successful application of crude sewage to waste and sandy lands, which have thereby been converted into useful and fertile soils, repaying with rich crops the cost of irrigating them.

In interior, isolated cases, the distribution of the sewage through drain pipes laid underground has been successful.

In general the anticipations that a commercial profit could be realized from the several methods of treating sewage, have not been justified in practice, and the sewage problem is mainly considered from the point of view of the protection of the public health, and the preservation of the purity of water supply. In many cases, however, where the circumstances are favorable, the utilization of sewage has proved profitable.

The important relation of an ample and wholesome water supply to the growth and prosperity of cities, has grown to be a matter of universal acknowledgment, and has led to the partial specialization of engineering work of this kind.

It is probable that in general the waters of flowing streams

must be looked to for the supply of that necessary element of life, and when such is the case, with the exclusion of sewage and proper filtration, the waters may be preserved in a comparatively pure and wholesome condition. But in most cases streams have been used both for water supply and as waste channels for the riddance of sewage, and the difficulties of avoiding this are often so great that the prevention of pollution has taken rather the form of purification than of absolute exclusion. It must be admitted, however, that neither the most complete chemical treatment nor the most elaborate filtering can render entirely innocuous for drinking purposes a stream that has once been polluted with sewage. The germs of zymotic diseases, of which water is now recognized as a common distributor, have, under actual tests, exhibited a wonderful tenacity of life and power of multiplication. Unfortunately the most refined chemical analysis must fail to disclose the existence of these in drinking water, and the only absolute security is either to thoroughly protect the stream from pollution, or have recourse to other sources of less physical disadvantage.

Projects for improved water supply are multiplying over the country, and nearly all the great cities and numerous smaller ones are earnestly pressing for a solution of the water problem.

New York has let contracts for the construction of a new aqueduct, at a cost in excess of $12,000,000. Boston and Brooklyn are considering how to increase their supply. Chicago is contemplating the extension of her lake conduit, and the erection of a more powerful plant. Philadelphia is seeking a new source of greater volume and purity, and meanwhile is endeavoring by preventive measures to reduce the pollution of the existing supply.

The extensive and fatal outbreak of Asiatic cholera in Europe —sacrificing thousands of lives in Italy, France and Spain—has powerfully stimulated public thought, and led to energetic measures for the protection of our own people against the threatened invasion of the dread visitor.

Cholera is essentially a filth disease, born in corruption, and disseminated by personal contact and the absorption of the germs in drinking water. The weapons most effectual against it are

decency and cleanliness. In the presence of these its poisonous breath becomes comparatively harmless and its vitality is lost. The lesson is one which a child may learn at a glance.

City engineering, covering all the various works essential to the conditions of municipal life, has developed in many directions. In particular has the matter of internal transportation received great attention. The cable system of street railways, which had its birth in San Francisco and received its greatest development in Chicago, has been adopted in numerous other cities, and crossed the ocean to Europe. Philadelphia has an extensive plant under construction and about to be tested. New York and Brooklyn are about to try it. London has laid a short line, and Edinburgh proposes to adopt it.

The cable system has so many excellent advantages over the defective system of horse transportation, in which the wretched animals slip and strain with the heavy loads, and wear themselves out in three or four years, that it is to be earnestly hoped that one satisfactory solution of surface traffic has been reached. This will always be required, even should elevated and underground systems be adopted for more rapid transit over greater distances. For these, good authorities estimate that the elevated system can be operated by means of electricity at a saving of 20 to 30 per cent. over the cost of steam, with the advantage of the avoidance of vapors and gases, reduction in the weight of the motors, and diminished annoyance to passers beneath.

The wholesale distribution of steam for heating and power from a central station, has had a successful trial in New York, and a company proposes its introduction in Philadelphia. The extension of this system under proper regulations, is undoubtedly a step in the right direction, as reducing cost to individual consumers and conserving the public safety.

As regards her own engineering work proper, including the matters of water supply, sewerage, highways, bridges, street paving, cleaning and lighting, fire protection and the guardianship of the public health, Philadelphia fails to occupy her proper position among the great cities of the world, and to set that example of "good works" which the wealth, intelligence and virtue of this ancient corporation would be ample to furnish were proper direction given to her energies and expenditures.

While the serious disadvantages to the health and wealth of the community of a water supply notoriously insufficient in quantity and grievously polluted in quality have been fully set forth, and while therefore public attention has been earnestly directed to the necessity for its improvement, the immediate steps requisite for the suppression of pollution even at our very doors, are apparently taken with the utmost reluctance, while the advance toward increased facilities for storage and distribution, and the construction of the new works necessary to the future satisfactory supply of the city, are made with such slowness and deliberation as to relegate the prospect of their completion rather to the domain of hope than that of anticipation.

The streets are covered with a pavement which, in all well regulated cities, has long since been abandoned as costly to traffic, impossible to clean, permeable to street fluids, noisy and hopelessly disreputable. But one really suitable bridge across the Schuylkill exists, when there should be at least six and preferably a dozen. One is partly in ruins, another is in process of patching to keep it from falling, a third has been condemned for traffic.

The Fire Department labors under most serious disadvantages from lack of water, obstructed mains and obsolete fire hydrants.

The city sewers are without proper means of flushing or cleaning, and many are so constructed as to waste their contents by leaking. In consequence, the foul matters either to a great extent are stored under the pavements to evolve poisonous vapors and drive them into houses, or saturate the soil on which the dwellings are constructed. Several of them discharge their contents directly into the pool whence the water is pumped for the supply of our people.

The health authorities, charged with the responsibility for the public health, and in many particulars armed with ample legal power, are crippled in their efforts by the lack of means for the accomplishment of most urgent work.

I do not hesitate to invite your attention to these matters, for the reason that in a community like our own they cannot and should not be hidden from the public, and unless set forth in their true relation to the public interest, will fail of amendment.

I would not have it understood that no progress is being made in useful directions. Improvements are really making, but other communities are proceeding with greater energy and swiftness, and we are relatively falling behind.

I look forward with the eye of Hope to the future engineering work of the city. A water supply pure and abundant beyond possible domestic and manufacturing requirements, furnished to the citizens at a minimum of cost, with an ample reserve for the frequent and regular flushing of sewers, and the beautifying and refreshing play of numerous fountains. For this, the Water Department has been surveying and laboring for two years past, and is now preparing plans and estimates.

The streets clean and well lighted, covered with water-tight and durable pavements, of construction adapted to the particular kind and amount of traffic using them—on Delaware Avenue, for example, massive and enduring; on driving, shopping and residence streets, smooth and noiseless. It is hoped, also, that means will be found to open a suitable approach to our superb Park from the old city, and that the mud and dust experiment of Twenty-second Street will not be repeated.

The report recently made to the city, by General Gillmore, Captain Greene and Mr. North, constitutes as good a practical guide in these directions as could be desired, although personally I should like to see tried an experiment with wood pavements as now laid down in London and Paris.

The new bridges over the Schuylkill for more convenient intercommunication between West Philadelphia and the old city should conform strictly to the grades of the streets connected by them, in order that there may be the least obstruction to traffic. The head room beneath need not be more than sufficient for the passage of the casual tug boat after laying her smoke stack back upon the deck. The rapid transportation of the population in decency and comfort from point to point will be provided for by surface roads, operated either by cable or electricity. For the larger systems, electric elevated roads will be required, and the pioneer of these might well occupy, throughout its length, such a capacious business street as Market, and transfer its passengers with certainty and expedition from the Delaware to West Philadelphia, passing noiselessly by the City Hall.

I anticipate the reconstruction and modification of the sewers upon a thoroughly considered and scientific system, carefully adapted to the special requirements of the several portions of the great expanse of the city jurisdiction; all regularly inspected, cleaned and flushed. The fluid waste should be intercepted along suitable lines, and instead (as now) of being discharged into the rivers, to pass and re-pass on every tide, poisoning the atmosphere of the city front, and eventually fouling the docks and channels with deposits,—be conducted under the Delaware, and sent out in a suitable conduit to enrich the thirsty soil of New Jersey, which only awaits this application to become, in the highest degree, productive. The lands on the Pennsylvania side of the river are already too heavy and wet for this purpose—for example, the diked islands below the city, the surfaces of which are from 1 to 4 feet below high-water; and the presence of the light, warm and permeable New Jersey lands immediately in front of the city, stretching away in all directions, and abundantly able to receive and dispose of the entire sewage of Philadelphia with benefit to both city and country, constitutes one of the most favorable possible conditions for the advantageous disposition of sewage.

The solid waste matters of the city, instead of being thrown into the sewers to choke them, or deposited in open spaces, to infect later the dwellings erected thereon, should be collected and sorted, whatever may be of value suitably treated and disposed of, and the remainder reduced by the action of heat to a condition of innocuousness.

In our narrow streets, the multiplication of numerous underground conduits of the several kinds—for sewage, water, gas, electricity and steam—has become a source of great perplexity and expense. It is readily seen that were suitable subways or tunnels constructed along the most important lines of communication, all these conduits could be accommodated, introduced, repaired, and, if necessary, removed at little cost and with entire avoidance of the destruction of the street pavement and the interruption to traffic.

The cost of such a subway on Chestnut Street, for example would in the end be less than the perpetual tearing up of the

street and the severing of house connections due to the present method of independent individual action by companies and City Departments.

The urgent present need of Philadelphia, is the effective and intelligent combination of sound business methods with sound engineering principles, since not one of the topics referred to but affects most intimately and vitally the public weal; and the gradual development and construction of the great public works needed to relieve Philadelphia from the depression of her existing physical disadvantages and elevate her to her proper position as a great metropolis, will demand the utmost knowledge and foresight, and eventually call into action the highest achievements of engineering science.

To you as Engineers, must the direction and execution of these works be hereafter entrusted, and no higher mission is given to the lover of his profession than that of serving and, if possible, benefiting a community which now contains nearly one million people, and within less than a generation will be the home of double that number. May the work be wisely projected, faithfully executed, and triumphantly completed, and may we all be here to witness the happy consummation, though it be with wrinkled front and staff in hand.

During the past year Philadelphia has been specially favored as a point of concentration of scientific workers. The British Association for the Advancement of Science met in Montreal in August, for the first time in its long and brilliant history on American soil, and many of its members honored us with a visit in consequence of the meeting in Philadelphia of the kindred American Association, and the opening in September of the Philadelphia Electrical Exhibition, under the auspices of the Franklin Institute. Of the notable success of this as an exposition of the progress made in the varied applications of electricity, we were all witnesses.

Other important conferences have been held. An international prime meridian was adopted in Washington, that of Greenwich being approved by all, with the exception of a few national representatives whose scientific and practical consideration of this important matter was subordinated somewhat to their patriotic susceptibilities.

The conference in Paris in May fixed the Ohm, the electrical unit of resistance, as that of a column of mercury at 0° cent., 1 mm. in section, and 106 cent. in length, and this standard has been accepted.

The Health Exhibition in London which was opened in May and closed in October, was of immense value in the instruction of the public as to the laws of health and good sanitation; and the projected World's Exhibition in New Orleans for the present year, will continue the good work of the Philadelphia Centennial in the promotion of knowledge and acquaintance with the work and progress of other nations.

Our own organization, gentlemen, has enjoyed a period of unexampled prosperity. The net increase in our membership has been from 244 to 363, or nearly 50 per cent., the largest in our history.

The hand of death has fallen upon four of our number, beginning with our Past President, Strickland Kneass, then Faunt Le Roy and Wootten, and finally our distinguished fellow-member, William Lorenz.

The Club has been active during the year, and numerous papers of interest and value have been read and discussed, and recorded for the enrichment of our journal. Prominent among these I may refer to the discussion by Prof. Haupt, of the interesting subject of the correlation of the means of Transit with the Growth of Cities, which in its clear and thoughtful elucidation of the topic is a valuable contribution to the domain of City Engineering.

The inadequate space afforded for meetings in our present quarters, lend renewed urgency to the question of securing greater accommodations in a building specially devoted to our own purposes. It was hoped that by this time permanent quarters would have been secured, but the change of plan by the Trustees of the Girard Estate deprived us of the very suitable house which had been engaged, and advertisement failed to elicit the proffer of a suitable one.

I believe that there is no difference of opinion among us as to the advantages of a greater degree of social and professional intercourse than is now possible. The organization has only just embarked, as

it were, upon its future career of usefulness and distinction. It is destined to embody the best thought and the most active minds and work of the profession, and the young men of to-day will in a few years be leaders. Nearly one-half of the present members have their homes and occupations beyond the limits of the city, and the report of the Secretary shows how widely they are distributed over the world.

In this connection I would suggest that a change of designation is desirable. The word "Club" is one which, in the ordinary sense, is not applicable to our organization, and to the general public is somewhat misleading as to our work and occupations. I have given this subject some thought, and believe that it would be wise to change our present designation to that of the Philadelphia Association of Engineers, or such other as shall seem most suitable.

Philadelphia, which was formerly the heart of our political system, and is now in many respects the acknowledged conservator of scientific thought, may well become also a centre of Engineering Science, which should include within its influence the broadest field. I commend this suggestion to your consideration.

I have sought in this address, in such imperfect manner as my opportunities have enabled me, to convey to you a few thoughts in regard to our profession and suggestions as to the work expected of us. The sphere of the Engineer is broad and high, and his ambition and purpose should correspond thereto. I have endeavored to set this before you, to indicate in what direction lies, to my apprehension, the highway of success, and in particular to touch upon the more immediate problems which lie closest to us at home, and affect the City and State.

When your respective turns shall come to discharge the duty which is laid upon me this evening, you will appreciate my feeling of inadequacy in the treatment of so weighty a subject, and of how far I fall short of an ideal presentation of its many aspects.

In surrendering the Chair at the termination of this, the seventh year of our organization, it is proper that I should refer to the unfailing interest and faithful service of our Secretary and Treasurer. There is a saying in the Army that a company of soldiers is better off with a good 1st Sergeant and an indifferent Captain

than with a good Captain and a poor 1st Sergeant. It may be for this reason that we change our Presidents every year and keep the same Secretary.

In conclusion, gentlemen, it behooves me to thank you one and all for the kind consideration you have shown me, to express to you my best wishes for your continued health and prosperity, and to assure you that, whether as a color bearer or a high private in the rear rank, the interests of the organization are mine, and whatever I can do to advance them will be done with pride and pleasure in the doing.

OPENING ADDRESS

of Joseph J. de Kinder, President.

On taking the Chair for 1885.

Presented January 10th, 1885.

Gentlemen:—Sincerely appreciating the distinction you have conferred upon me this evening, by electing me to the Presidency of the Club, I ask you to accept my heartfelt thanks, and the assurance that it will continue to be my pleasure to devote myself to the Club's best interest, confidently relying upon your earnest support.

I hope the present year will be marked by your increasing prosperity individually and as a Society. Let us increase our social intercourse, and let every one contribute, if but a fly-leaf, from his day-book of engineering experience, to the common good.

What may seem knowledge of trifling value to the owner, may be of vast importance to others. Any one of us, educated in the school of hard knocks, can remember *some time* when a hint from, perhaps, the humblest assistant was valuable indeed.

We tread a boundless field. New inventions, and applications of inventions, are daily heralded from all parts of civilization. Few of us are able to confine ourselves strictly within the limits of one branch of the profession. Often are we called upon to

wrestle with a knotty problem, without precedent probably, when hard sense born from experience, and may be sad experience, must come to our aid. The benefit of just such problems, when met and conquered by any member, would I have him give to his fellow-members.

Thanking you again for this distinguished honor, I take the chair with the best of wishes for 1885.

XIX.

AN IMPROVEMENT ON THE EGE-WALTER PROTRACTOR

By A. E. Lehman, Member of the Club.

Read June 7th, 1884.

This instrument was originally intended for use by mechanics only, was afterwards changed so as to be suitable for architects' use, and since then slightly re-modelled so as to be of limited use as a protractor. It is thus briefly described:

In its incomplete state it consisted principally of a circular arc graduated into degrees and fractions thereof, and a movable rule or blade, said rule being fixed on a movable chair or revolving circle, inclosed within the arc and about four-fifths of its diameter. The rule is articulated to, and oscillates freely about, the centre of the circle; one end of said rule or blade being made co-incident with the radii, and hence passes through the centre of the circle.

The instrument was put into my hands by the inventors for examination. I found it very incomplete; too good for a mechanic's use, and yet lacking qualities which it should possess to be what an engineer or surveyor would require in a protractor.

After carefully looking the instrument over and making some use of it, the following changes and improvements suggested themselves:

1. The metal on the right hand side of the circle at *A.A.A.A.* should be removed so as to produce a perfectly defined graduated half circle.

2. That the edge of said half circle or arc be beveled.

3. The graduations to be extended out so as to fully cover the beveled edge of circle *A.A.A.A.* so that instrument can be used with the arm *B.B.*, removed as freely as an ordinary ivory or paper protractor.

4. Scales put on chair or revolving circle at *C.C.C.*

5. Opening in revolving chair at *D.D.D.* elongated and enlarged so as to amplify space intended for scales *C.C.C.*

6. Blade or arm lengthened at left hand end, that it may cover graduations there and corresponding points and zeros on both sides of the arc.

7. Arm notched out from *E.* to *F.* to enable the centre of instrument at *C.* and scales *C.C.* to be more easily seen.

8. Bevel on arm to extend from end to end, and also on opposite or reverse side the full length.

9. Various scales engraved on arm similar to those usually found on ivory protractors.

The accompanying illustrations show the finished and improved form of protractor, made from drawings furnished by me.

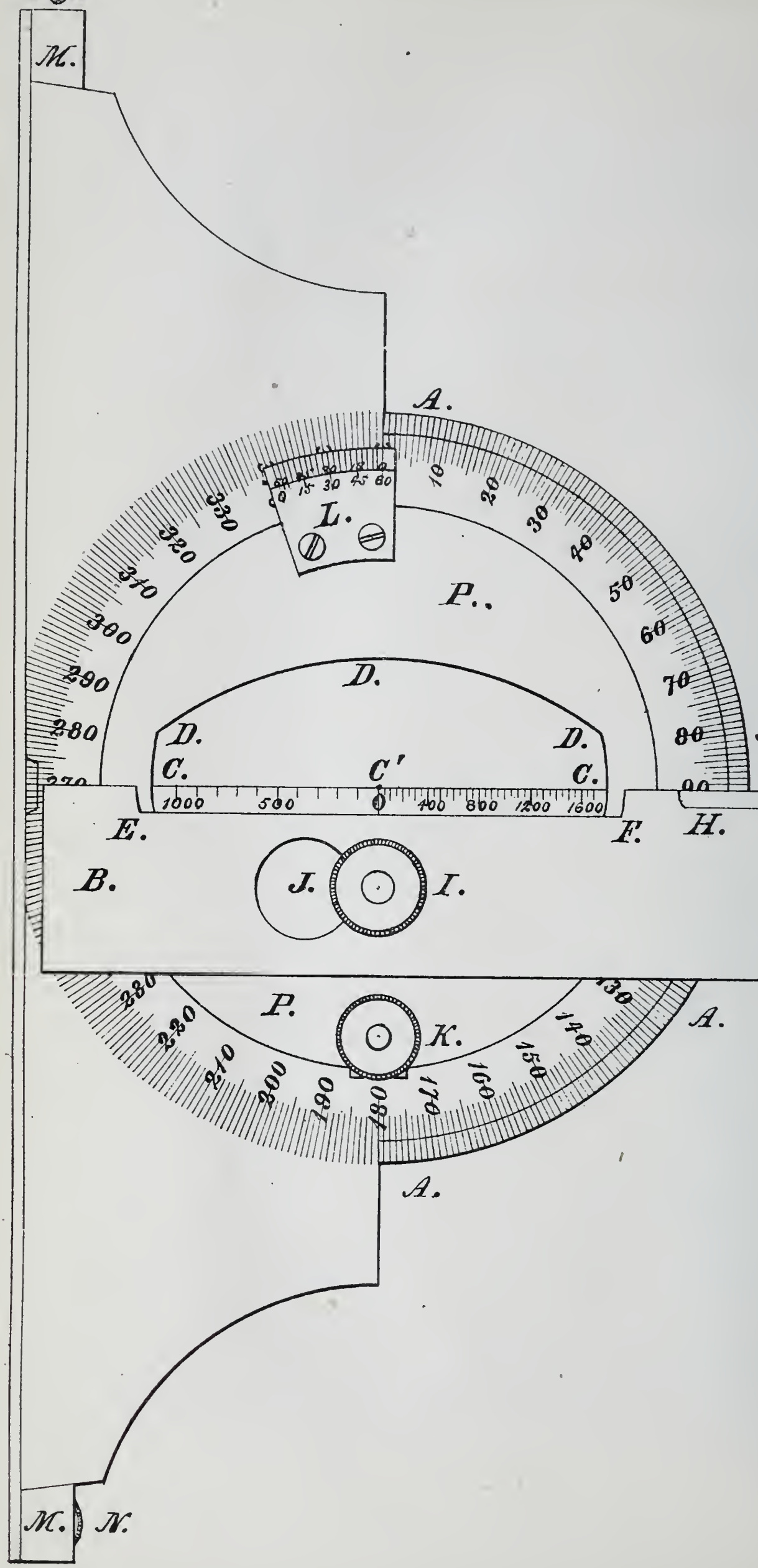
Referring to the plate, Fig. 1 shows a side view of the improved instrument. Fig. 2 is a plan view of the same. The figures do not have to be described in detail; by reference to them the functions and utility of the device may be readily understood. However, besides what I have elsewhere explained, I may say that the large milled-head screw at *I.* shows the clamping arrangement for the arm *B.B.* to the movable chair *P.P.*, firmness being secured by lugs attached to the arm and fitting into said chair.

At *J.* there is an elongated hole or slot to allow the arm to be removed and replaced when required. The small milled-head screw at *K.* is a clamp for the revolving chair. At *L.* a vernier, reading to three minutes, is shown, which moves with perfect ease and stability around the graduated circle. The vernier is made of brass, the object of this difference in metal from the other parts of the instrument—which are of German silver—being to produce a pleasant contrast in color, resulting in less strain and relief to the eye when using the protractor. The vernier is brought into position by moving the arm *B.B.*

M.M.M. shows an adjustable rule or edge which can be taken off

LEH

THE E



Actual

ig. 1

PROC. ENG. CLUB OF PHILA., 1885.

)L. IV, NO. 5. PLATE XVI.

IAN — IMPROVEMENT ON
E-WALTER PROTRACTOR

B.

ig. 2

Size.

and replaced at will by the clamp screw *N*. With this appliance and the arm swung one-half around to *O*., the instrument can be used as a **T** square. To make it more efficient in this respect an extra rule similar to *B.B.* of any length desired is provided.

The open work *D.D.D.* in the centre of the revolving chair is so constructed as not to weaken co-operating parts, and the edge of the blade is cut away so as not to encroach upon the functional lines pertaining to the centre, radii and scales of the instrument.

In practice an arrangement is made for adjustable scales, thus making the utility of this feature of the instrument unlimited.

This improved instrument, as above described, has a wide range of adaptation to engineers', architects' and surveyors' work.

The advantage of this protractor over those in ordinary use may be readily seen by those skilled in the use of such instruments. It is due mainly to the combination of protractor, scales and **T** square, which may be worked separately, or together. In general principles its conscruction differs materially from others manufactured. Even with the appendages described, it is more simple than the Cleaver Protractor, and vastly more convenient and capable than the Swiss Protractor, so popular and in such general use. One of the most serious faults of the latter is the exceedingly fine graduation. It is doubtful if it can be safely used without the aid of a magnifying glass. The need of a new combination instrument has often forced itself on my attention as a substitute for the numerous tools needed in a complete plotting outfit, such as paper protractor, scales, triangles, etc. The instrument here presented embodies all these and other important qualifications of a good protractor. It costs no more than any other of this class in the market.

I have found in my practice that the most expeditious, simple and accurate way to plot lines run with stadia measurements, is to do the preliminary work on profile paper. During the last five years I have plotted some thirteen hundred miles of topographical and railroad lines in this way with very satisfactory results. Heretofore I have used an 8-inch paper protractor, a small straight edge and Lesley's Micrometer. The latter, while a most useful and ingenious instrument, is constantly liable to get out of adjustment through hurried handling, its parts being very delicate.

With the improved instrument here introduced, plotting on profile paper can be done with even greater facility. For doing this work the proper position of the paper is with the single foot-lines running north and south. These lines being close together, where a station or point comes between them the protractor can be centered and oriented between them with sufficient accuracy to keep up the necessary parallelism in carrying the north and south line over the paper. After turning off the bearing with the blade and vernier of the instrument, the distance is drawn from the centre at $C.^1$ according to scale along the edge *C.C.* in the required direction. After all the lines are plotted and connected in this preliminary way, it is a small matter to prick them through and transfer them to the paper on which the finished map is to be made. I have found Queen's plate A. green, the best and most accurate profile paper to use for this purpose.

The strain upon the nerves in using a number of separate instruments with the care necessary to do so properly, is more than we should endure. Every one who has constructed elaborate maps extending over a large area of country, will agree with me in this assertion.

Considering also the liability of error when several instruments are used together, as have heretofore been necessary in such work, there may be much advantage gained by use of this contrivance. It certainly amplifies the scope of such implements to the needs of engineers, surveyors and architects.

XX.

THE KAOLIN BEDS OF CHESTER CO., PA., AND OF NEW-CASTLE CO., DEL.

By Graham Spencer, Member of the Club.

Read November 15th, 1884.

For the last fifty years the manufacture of china in this country has been steadily growing, and is now an important industry, and one that is increasing in the quantity, as well as quality of its goods, yearly. The first pottery in America was established in Philadelphia, about half a century ago, by a man named

Tucker, who carried on the business for some time, making very excellent semi-porcelain ware. Since then, Trenton, New Jersey, is the great point of manufacture east of, and East Liverpool, Ohio, west of, the Alleghenies. Besides these, Baltimore, Wheeling, Steubenville, Beaver Falls, and Cincinnati, and a number of other places have one or more potteries located in them.

The great bulk of kaolin, or china clay, used in the potteries of the United States, is mined in this section. The amount of prepared clay shipped last year, was nearly twenty thousand tons.

Kaolin results from the decomposition of a rock composed of felspar and quartz; and is found in pockets or beds, in low, and very often swampy ground, (I speak of kaolin found in this vicinity), the clay underlying the surface soil holding the water. The amount of covering varies; in some cases being less than eight feet from the surface, and in others as much as forty. The pockets are of an oblong shape, the general direction being N.E. and S.W. The kaolin is found bedded against veins of talc, which determine the width of the pocket. The talc is very irregular in its pitch, but eventually cuts the clay out. The talc is in turn bedded against partly decomposed mica-schist, and very often against a vein of iron or manganese.

There are no surface indications of kaolin, and it is generally proved by boring, or sinking small shafts. After having determined the position of the deposit, the dirt is stripped off and the clay uncovered, and taken out by means of carts, cars, or derricks, as the case may be. From the situation of the pit, which is generally in the lowest ground, there is no opportunity for drainage after you are down any depth, and constant pumping becomes necessary, not only of surface water, but of large springs which burst out from the sides of the pit, and through the banks.

The clay is taken from the pit to the washing machine, which is a three or four-inch shaft, according to the power you have, placed horizontally with knives at right angles, about four inches apart, made of three-inch by inch iron, twelve inches long. The whole is enclosed in a stout framework, with a pulley at one end of shaft connected by belt with main shaft, and an opening made at the other end of the machine for the escape of the clay and sand. The shaft is set in motion, a stream of water turned on,

and the clay thrown in the top as fast as a man can shovel it. The sand or quartz coming out with clay and water, settles in a box, where it is continually being shoveled out.

The clay, combining with water, and of the thickness of cream, is allowed to run slowly off into a number of troughs for a time, until all the impurities have had a chance to settle. It is then turned into large vats, where it remains until quite thick. It is then pumped into presses, which are a number of wooden panels held together by iron rods—each panel containing a canvas bag. The water escapes through the pores of the canvas, and leaves the clay in such condition that it can be handled and placed on shelves in the open air to dry, after which it is ready for shipment.

Kaolin, both in a crude state and washed, is much improved by exposure. If placed in piles, and allowed to freeze and thaw during the winter, it will be found much tougher in the spring. A strong, tough clay is of much more value to the potters, as it enables them to make thinner ware. It is said that in the manufacture of the finest ware, in China, one generation mines the clay for the next to use.

The average yield of washed kaolin from a ton of crude clay is from thirty to fifty per cent. I have never seen crude clay in any quantity which would yield above that.

The quartz, washed from the crude clay, is of the purest nature; and when pulverized is worth about $12.00 per ton, and is sold to the potters—they using it in the body of their ware—and also with felspar, as a glaze.

The mica or talc which is washed from the clay, and settles in the troughs, makes a good fire-brick.

In conclusion, to give a general idea of the size of the deposits of kaolin in this section, I would say that in the pit I am now working, the clay had been proved at a depth of ten to sixteen feet from the surface, for over 300 feet in length, and 80 to 100 feet in breadth; and in depth 50 feet, and still clay. The greatest depth I have ever been down, in any of my pits, is ninety feet, the strata of clay continuing, but which had to be abandoned on account of the expense of keeping the dirt from caving in.

The color of kaolin varies from a pure white to a yellow (as

shown in the specimens), the white being more valuable. The yellow and the white clay are often found banked against each other, and running vertically downwards, side by side. The clay is hard to excavate, and requires the strongest steel-pointed shovel for work, being dug in sods.

XXI.

ON THE ADAPTATION OF MOVABLE DAMS TO THE OHIO AND OTHER RIVERS OF THE UNITED STATES AS PRACTICED BY THE UNITED STATES CORPS OF ENGINEERS.

By Prof. Lewis M. Haupt, Member of the Club.

Read December 6th, 1884.

DATA.

Reports of Cols. Craighill, Merrill and their assistants to the Chief of Engineers; of various Boards of Engineers detailed to examine and report upon said works. Personal inspection of the work at Davis Island, and an extensive correspondence. Due acknowledgement is herein made by references embodied in the text.

Introduction.

The problem of the improvement of the Ohio River and its tributaries has engaged the attention of the Civil and Military Engineers of the United States for many years, but it is not proposed to detail the history of these projects further than to show the condition of the science at the time when the present works were undertaken and the recent modifications, which have rendered the application of the "French Dams" of Mr. Chanoine possible on so large a scale.

Among the early projects was that of the improvement by dams and dikes begun on the Ohio in 1836, and which proved so successful that it was subsequently extended.

Another plan was suggested by Chas. Ellet, Jr., C. E., in 1850, which consisted of large storage reservoirs in the mountains of adjacent States from which it was proposed to keep up the required stage of water, but it was never put in operation. More

recently it was proposed to improve by combining (1) the contraction of the width of the channel by building lateral dams, with (2) the reduction of the slope of the river bed by bottom dams, and (3) the retardation of the flow by the use of removable obstructions.

Having maturely considered these various projects, a Board of United States Engineers, composed of General G. Weitzel (deceased) and Col. Wm. Merrill, was appointed to "report upon the applicability of Hydraulic Gates and Dams in the Ohio River."

Their exhaustive report was made to the Chief of Engineers *January* 31*st*, 1874, and contains a description of all the improvements of this character then known to exist. It contains some extracts from the descriptions of MM. Hagen and Becker, of the existing movable dams on the continent of Europe and especially in France. In their introduction the Board say,* in reference to the use of the system on the Ohio: "The average width of a coal fleet is 125 ft. The least width of chute that can now, in advance of experience, be assumed as necessary, is two hundred (200) feet. The first question, therefore, is: Can a gate be constructed that can be made to close or open this passage at will?

"The following extracts from Hagen and Becker will show what has thus far been done in this country and Europe. . . . . Hagen remarks in his preface, 'No one of the different plans that have been suggested seems yet to furnish a full solution of the problem,' and he adds:

"'A complete solution . . . seems to require that the pressure of the water, whether standing or flowing, should furnish the power by which the dam is erected or removed. Or, again, the construction must be such that, notwithstanding the requisite solidity of the structure, it can be managed with a slight power, for which only a few men and a short time are required.'"

Then follows a description of all of the methods which the Board could obtain, that had been used up to that time for the management of hydraulic gates or movable dams. "The following are the methods thus far described: (1) the Bear Trap; (2) the wicket used on the Riom; (3) Thénard shutters; (4) Thénard shutters modified by Fouracres; (5) Poirée needle-dam; (6)

* Ex. Doc. No. 78, H. of Rep., 43d Cong., 2d Session, page 3.

Poirée and Thénard combined; (7) Chanoine wickets; (8) Desfontaines wickets; (9) modified Poirée needle-dam; (10) Cuvinot drum wickets; (11) Krantz wickets, with ponton; (12) Carro gates; (13) Girard shutters."

Since the preparation of the reports above mentioned, numerous other solutions have been presented for the general problem as stated by Mr. Hagen, and many modifications have been made in detail, by which the application of existing methods are made more efficient and far reaching.

History.

Under this head I can merely outline, in the most general manner, the steps taken to apply the system as now used in France to American rivers.

Prior to August, 1874, Col. Wm. E. Merrill, United States Engineer, was in charge of the improvement of the rivers of the Ohio basin, and to him more than to any other person is due the credit of examining, testing and applying this system. He has reviewed the subject completely, translating all the available foreign literature relating to it, and has made numerous special reports and recommendations thereon, both separately and in connection with other officers. As early as April 16th, 1872, the then Chief of Engineers, General A. A. Humphreys, issued a Special Order No. 44, constituting Gen. G. Weitzel and Col. Wm. E. Merrill a Board "to examine and report upon the plan of Mr. F. R. Brunot for movable hydraulic gates for chutes and locks, its applicability to the improvement of the Ohio and other rivers, and an estimate of the cost of construction." To this duty was subsequently (May 1st, 1872) added the general consideration of the whole subject of hydraulic gates. A preliminary report was made January 14th, 1873, recommending an appropriation of $40,000 to make a test on the Monongahela, but without reference to any particular plan. A full report of all the then known devices was made on January 31st, 1874, in which the members of the Board say "they are now prepared to submit a plan which they feel confident will fully meet the necessities of the case." What this plan was is best given in Col. Merrill's Report, N. 1 of September 1st, 1874,* where he says: "After long study I

* Report of Chief of Engineers, 1874, p. 406.

have come to the conclusion that the best method of improving the Ohio, at least in the upper part of its course, is to follow the plans that have been so successful on the Seine, Yonne, Marne, Meuse and other French rivers. . . . The system that meets with most favor in France is that known from its inventor as the Chanoine." Before proceeding to describe this system it will be necessary to state in this connection that, pending the efforts of Col. Merrill to remove the legal obstructions to the erection of movable dams on the Ohio, several such dams were begun on the Great Kanawha by Col. Wm. P. Craighill, who was placed in charge of the improvements of that and other rivers in August, 1874. In recommending the adoption of the system in this district Col. Craighill, in a letter to the Chief of Engineers, dated April 30th, 1875, says: "The adoption of movable dams seems the best expedient available, as the system is used, for instance, on the Seine, and as described in the report of Majors Weitzel and Merrill. These will furnish an unobstructed navigation during . . . not less than six months in each year. The system has not been fairly tested in this country, but its long successful use in France would seem to supply the deficiency and justify its adoption under favorable conditions, such as are found on the Kanawha. . . . I incline decidedly to the use of the Chanoine movable dam at this locality (near Brownstown*) and at all points below and perhaps some above it. . . . Were I free to proceed, I should apply the available appropriation to the construction of a lock with movable dam near Brownstown . . making the lock 300 ft. long in the clear, 50 ft. wide, with a lift of about 8 ft., the dams to have a navigation-pass of 250 or 300 ft., arranged according to the Chanoine plan. . . The cost would be $286,000."

The project having been approved, contracts were made for building the lock, near Brownstown, August 20th, 1875, and for the dam, abutment, pier and floor of a navigation-pass adjoining, on March 28th, 1876. (The contract for lock No. 4, near Cabin Creek Shoal, was made October 15th, 1875.)

At the site of lock No. 5 the width of the river at low water is 575 ft.; between the tops of the banks, which are 45 to 50 ft. high,

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* Lock and Dam, No. 5. Report of 1875, Part II, pp. 90, et seq.

it is 800 ft. The average depth to river bed, in low water, is 4 ft. The navigable pass is 250 ft. long, and the weir is 265.42 ft. Dredging for the pass was commenced September 19th, 1877; the erection of the cofferdam September 26th. The lock of No. 5 was completed in August, 1878. The contractor for the dam abandoned his work in October of 1878, and it was continued by day's labor, under the Government. The pass of No. 5 was completed, except placing the wickets, on August 14th, and that of No. 4 on August 16th, 1879. The weirs at both sites were finished, ready to receive the wickets, on November 1st, 1879.

In his annual report for 1880, Colonel Craighill, says:* "At the date of this report (July 22d, 1880) locks and dams 4 and 5 are essentially finished, according to the Chanoine system, and usable." (The pictorial illustrations accompanying this report, probably made from photographs, show the dam up and a steamer passing through the lock, also various stages of the work during construction.)

In the report for 1881, Capt. E. H. Ruffner, U. S. E., says † of lock and dam No. 4:‡ "This work was practically completed on the 3d of July, 1880, when the first lockage was made.§ Since then the dam has been lowered and put up three times. It has been up a total of 146½ days to this date (June 1st, 1881)." . . . .

"The work on lock and dam No. 5 was completed so that the first lockage was made July 16th, 1880. Since that date it has been raised and lowered three times. It has been up a total of 122¾ days."

Thus it will be seen that, pending the consideration of the application of the system to so large a river as the Ohio, these two Chanoine movable dams, known as Nos. 4 and 5, were actually completed on the Great Kanawha, near Brownstown, in July, 1880, and were therefore the first in the United States.

The Davis Island Dam on the Ohio.

It having finally been decided to test the method on the Ohio,

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* P. 682, Part I, Report of Chief of Engineers, 1880.

† P. 913, Part I, Report of Chief of Engineers, 1881.

‡ Length of pass, 248 ft.; of weir, 210 ft.; pier, 10 ft.; of dam, 468 ft.

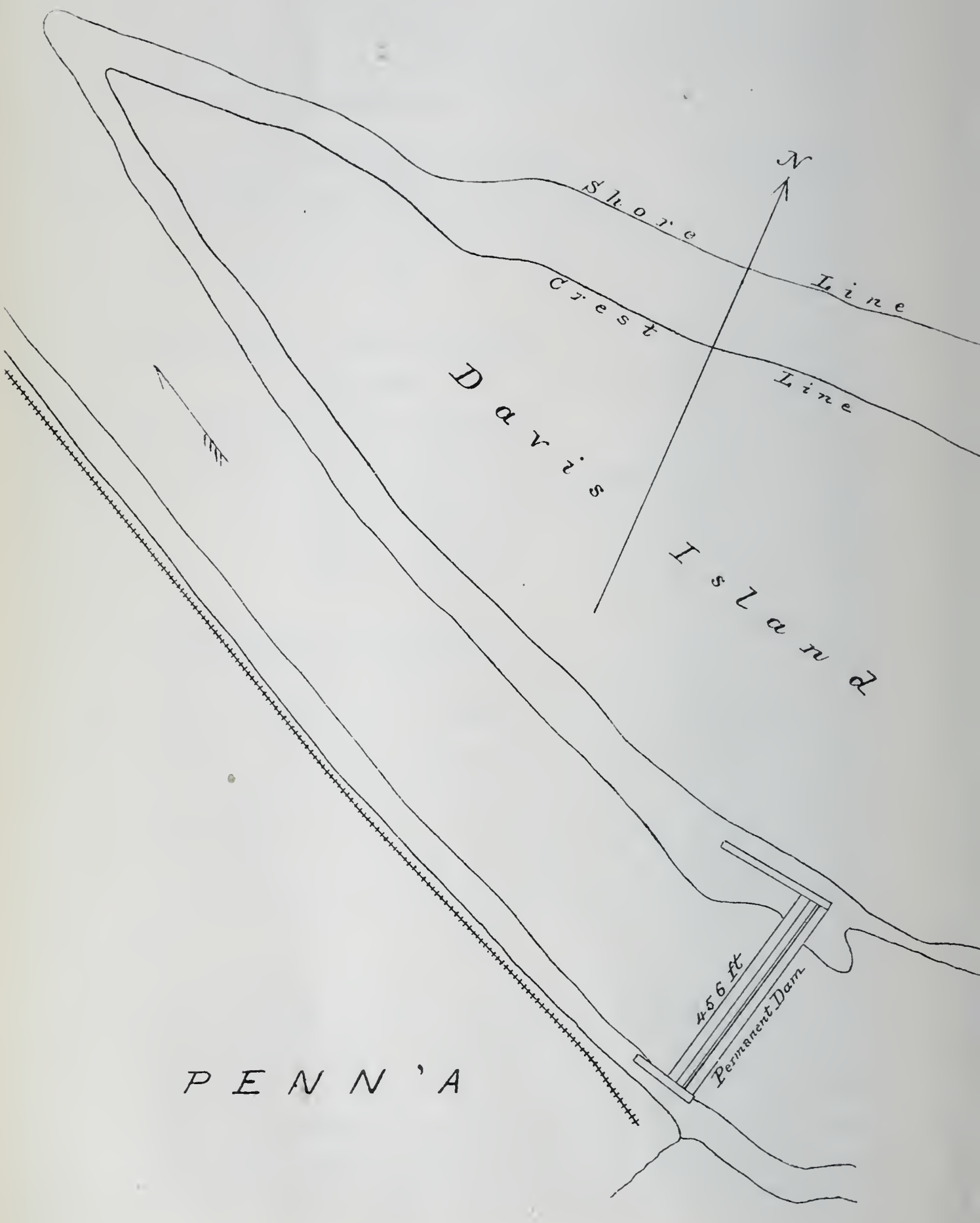
§ It was, therefore, the first Chanoine dam in the United States.

authority was given to begin work at the site of Davis' Island, 5½ miles below Pittsburgh, on July 24th, 1878, and in conformity therewith work was commenced on the 19th of August following. After numerous modifications the following dimensions were adopted as being those best adapted to fulfill the requirements of an extensive commerce:

Dimensions of lock chamber, in the clear, . .	600x110 ft.
Length of navigable pass (sill on river bed), . . .	559 "
" " weir No. 1 (sill 1 ft. above river bed), . .	224 "
" " " No. 2 (" 2 ft. " " "), . .	224 "
" " " No. 3 (" 3 ft. " " "), . .	216 "
Total length on main channel, ...	1223 "
" " with piers, ...	1260 "
Permanent dam across back channel, ...	456 "
Number of wickets (12′ 1½″ x 3′ 9″) in navigable pass, .	139
" " " (11′ 1½″ x 3′ 9″) on weir No. 1, . .	56
" " " (10′ 1½″ x 3′ 9″) " " No. 2, . .	56
" " " (9′ 1½″ x 3′ 9″) " " No. 3, . .	54
Total number of wickets, etc., ...	305
Additional wickets required for use in the lock, .	27

The wickets are spaced 4 ft. apart between centers, leaving 3 inches clearance. The first wicket was erected in presence of the Ohio River Commission, September 27th, 1881. The last of the pass wickets was put in October 29th, at 10 A.M. In the official report of the year ending July 1st, 1883, Col. Merrill says the weirs 1, 2 and 3 are completed, including the erection of a service bridge, from which the wickets of these weirs are to be handled.

At my last visit to this work I met Col. Merrill at the lock, and through his courtesy I was enabled to examine the details of the work and the drawings. I found there were 4 ft. of water on the sill of the dam, which was down, and that large "tows" had no difficulty in stemming the current, which at that place was quite rapid. The improvement is almost completed, as there only remains to be put in place the lock gates, with the turbines


N
Shore Line
Crest Line
Davis Island
456 ft
Permanent Dam
PENN 'A

General Plan of Lock and Dam at Davis Island.

June 30, 1883

and other machinery for operating them, which it is expected will be done next Spring.

The cost of the work it is difficult to obtain.

The estimate of the engineer in charge for 1879 was	$200,000
The same amount was asked for the year 1880 .	200,000
For 1881, ...	200,000
For 1882, ...	200,000
The reported expenditures for 1883 were, . .	208,594
The detailed estimate to complete the work, 1884–85, is	110,400
	$1,119,000

The amount of the unexpended balances is not known.

Lock No. 6 (for Movable Dam).

(On the Kanawha, 4 miles below Charleston and 54 above the mouth of the river.)

The improved Chanoine dam on the Kanawha was found to be so successful that another one, known as Dam No. 6, 558 ft. long,* was practically begun in the Spring of 1881 and nearly finished by July, 1883. It was estimated that it would be completed in three or four months thereafter. Dam No. 7† will also be made movable. Its site is 10 miles below No. 6, which is 13.2 below No. 5.

The Chanoine System of Movable Dams.

As this system has been selected by competent engineers after mature deliberation; has been put in operation on the Kanawha and Ohio Rivers, and has been found successful, and as its further introduction is only a question of time, I hope I will not be trenching too greatly upon your patience if I give a brief description of the system and the modifications which render it so successful.

The elements of the *barrage mobile* or movable dam are a wicket, a horse, a prop, a floor to support these several parts, and the devices for manœuvering them.

The wicket is merely a strong rectangular shield or panel, of variable dimensions, hinged to an axis placed at a height of one-

* 248 ft. of pass and 310 of weir. Lift of lock, 8¾ ft.

† 520 ft. long—248 ft. pass, 260 ft. weir, 12 ft. pier; 8¼ ft. lift.

third the length of the wicket from the bottom, for weirs, and of seven-twelfths the height for the passes.

The part of the wicket below this axis is called the *breech*, that above the *chase*.

To the same axis is hinged the head of an iron frame, called the *horse;* the feet of which are hinged to the floor of the pass, just behind the sill, so that when the wicket is raised its plane will be inclined down stream at an angle of 20°, while the horse will be inclined up stream at an angle of 5° from the vertical.

The *prop* makes an angle with the horizon of 37°. It is hinged at its upper end to the axis of oscillation of the wicket and at the foot it is supported by a cast iron block, called a *hurter*, which is rigidly bolted to the floor of the dam. The wickets are thrown down by means of a long iron bar extending across the dam, having projecting lugs, called *catches*, so spaced, that, as the bar is moved by means of a rack and pinion attached to the abutment, the feet of the props are "tripped" in succession, and, being drawn into a lateral groove, slide to the rear and allow the wickets to fall abruptly upon the floor of the pass. Counter-catches on this tripper-bar, equally spaced, at intervals corresponding to those between the centers of the wickets, prevent the props from being thrown down by floating bodies when the dam is up. The wickets are raised by means of a crab, placed in a manœuvering boat or on a service bridge, which is so constructed of iron trestles as to be folded down below the level of the sill after the dam is thrown, and thus offer no obstruction to navigation or to drift.

From this description it will be seen that the success of this system of movable dams for river improvements depends upon the co-operation of all the parts of the mechanism, and the application of the power at the proper times. The principal elements in these two factors are human vigilance and fidelity combined with mechanical possibilities.

The practical operation is best shown by quoting the results of experience, as given by Capt. Ruffner, with Dams Nos. 4 and 5 on the Kanawha, during the season of 1880–81.* In regard to

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* Report of Chief of Engineers, 1881, p. 914.

MANŒUVERING THE DAMS,

he says: "Although considerable trouble has been had, nothing serious has occurred, and the working on the whole has been as satisfactory as could be expected. The difficulties decrease with experience . . . As was to be anticipated, the tripping-bars have been the principal cause of trouble, and the desirability of getting rid of them, if possible, is clearly proved. They become foul from stone, gravel, sticks and cinders (the last is quite troublesome), that get on and *under* them and *in* the gearing wells. This is particularly the case when the dams are down, and a good deal of time and hard disagreeable work are always required to get the bars in working order before the wickets can be righted. Besides this they frequently fail to trip (the tripper passing the prop, as it will when the latter is not well down in its seat in the hurter), and the wicket is left standing to be pulled down from below, a slow and difficult operation. It is true that a careful examination of every prop by the diver in raising does away with the most of this difficulty, but not entirely, for a prop will sometimes be overlooked and cause the loss of precious time when the dam is thrown. It is believed that the adoption of the Pasqueau hurters* at both 4 and 5 is advisable, and it is respectfully recommended that steps be taken to give them a trial by placing them on one bar-section at one of the dams as soon as practicable."† . . .

Mr. A. M. Scott, Assistant Engineer, in reporting on the operation of the tripping-bar at No. 4 to July, 1883, is even more emphatic and specific. He says:‡ "This dam has been entirely up 143 days during the year. It was thrown down June 29th, 1882. It was put up July 10th in 10 hours and 15 minutes. Some

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* U. S. Patent No. 225533. Application filed, January 19th, 1880. Issued, March 16th, 1880, to Alfred Pasqueau, of Lyons, Department of the Rhone, France.

† As early as Aug. 9th, 1880, the Engineer in Charge of the Ohio River improvements, suggested the appointment of a Board of Engineers to consider the advisability of introducing the Pasqueau hurter and a straddling traveler for the Davis Island dams, both of which modifications were approved. See Supplement to this paper by Col. Wm. E. Merrill, published in Proceedings of Engineers' Club.

‡ Report of Mr. A. M. Scott, Assistant Engineer to Col. Wm. P. Craighill, U. S. Engineer on Dam No. 4, Great Kanawha River, West Virginia (Report of Chief of Engineers, 1883, Vol. I, p. 711).

delay was occasioned by a large rock found wedged under the tripping-bar. It was thrown again on the 13th in two hours, everything working right. Began to raise July 19th at 9.30 A.M.; finished on 22d at 5.15 P.M. Delay caused by lock section of tripping-bar being off the guides and a broken bed-plate in the gearing-wells. Dam thrown again for a rise August 20th* at 7.30 P.M.; all down at 10.30 P.M. Began to raise August 14th; finished 3 P.M. of 15th. Delay caused by broken pinion in lock gearing wells. Dam lowered September 1st in 1 hour and 45 minutes. Put up on 7th in 7 hours and 30 minutes.

The dam was lowered for a rise September 11th between 12.30 and 3.50 P.M. Three pass wickets failed to trip and were hooked down from below. The dam was raised September 25th and 26th in $9\frac{1}{4}$ hours.

It was again lowered for the Winter (a good deal of ice moving), December 8th and 9th; finished 5.10 P.M. The tripping-bar refused to work and the twenty-eight wickets were lowered with winch and hook. May 7th (1883) began to raise the dam. All up on the 21st. The pinions in both gearing wells were found broken. The repairs necessitated the removal and replacement of the shafts, bottom rollers, guides, etc., a troublesome and disagreeable job. The whole force and an extra man were at work most of the time, from the 9th to the 20th, in cleaning out the gearing wells, replacing the shafts and pinions, in short, in getting the tripping-bars in working order.

"The dam was lowered June 12th and 13th and raised again on the 18th. In lowering, three pass wickets failed to trip and were hooked down. The lowering of the bridge was much delayed by green brush and trees that had been cut and thrown in the river above. In raising $5\frac{1}{2}$ hours were taken in getting the pier tripper into gear, it having been pushed out too far after lowering."

From this description of operations during the fiscal year 1882–'83, it appears that the dam was lowered six and raised seven times. Total number of manœuvers 13. The least time required to raise the dam was 7 hours and 30 minutes, and to throw it down 1 hour and 45 minutes. Only twice in the raising

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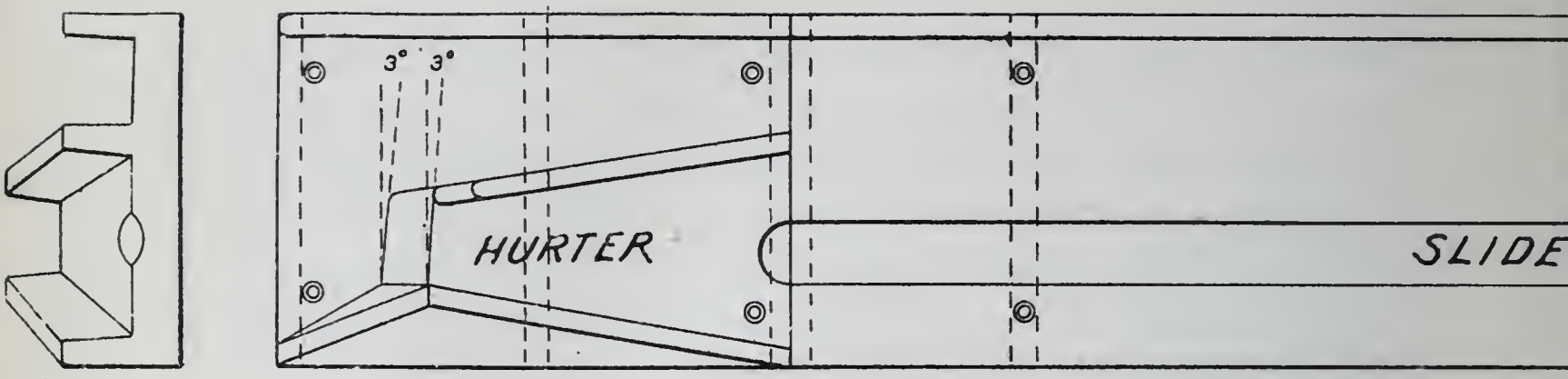
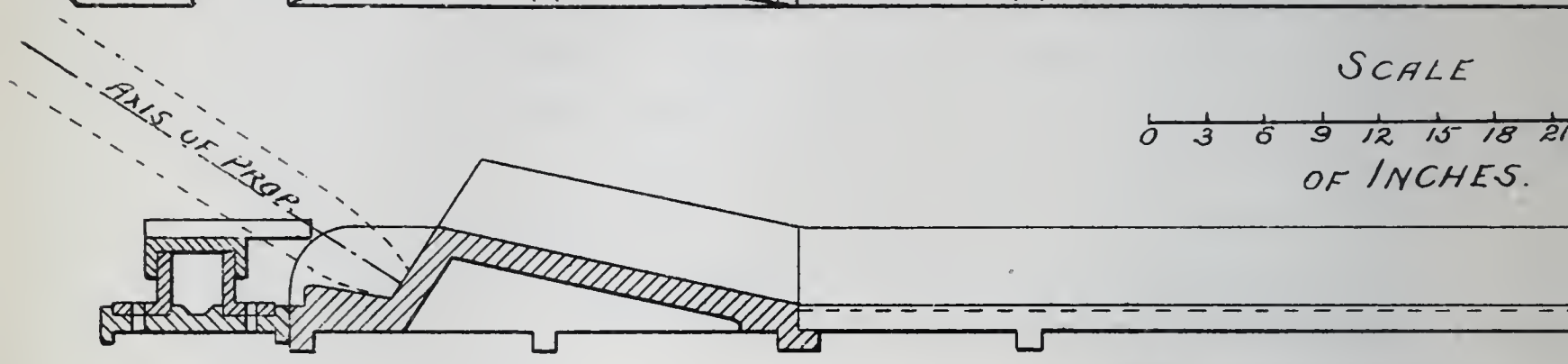
* Probably intended for 12th.



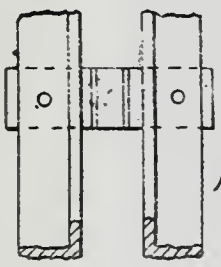


SCALE

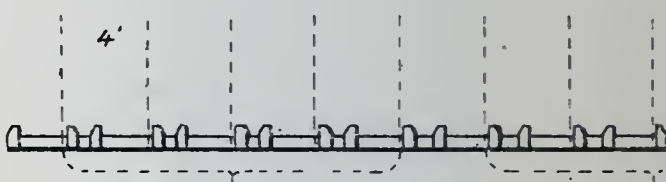
0 3 6 9 12 15 18 21

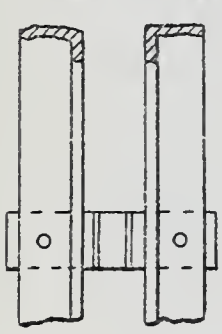
OF INCHES.

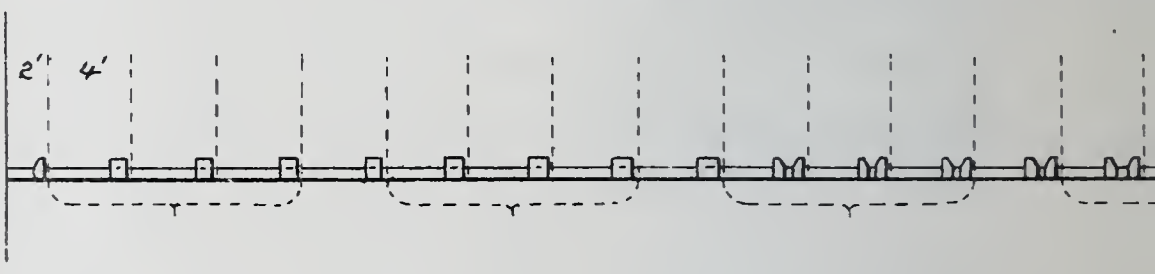
W.T = ABOUT 800 LBS.

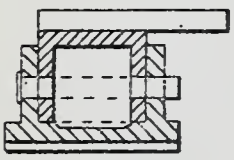


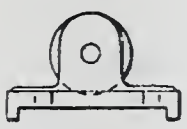
GUIDE
FOR TRIPPING BAR.

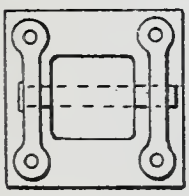




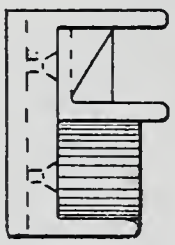


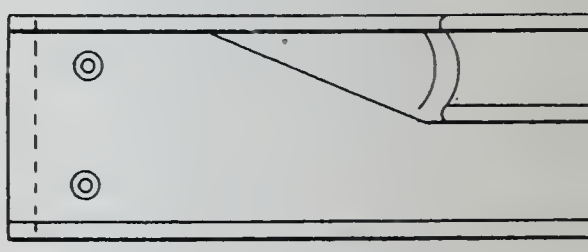






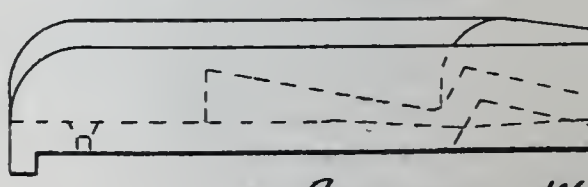
ROLLER
FOR TRIPPING BAR
ONE EVERY 8 FT.





0 3 6 9 12 15 18

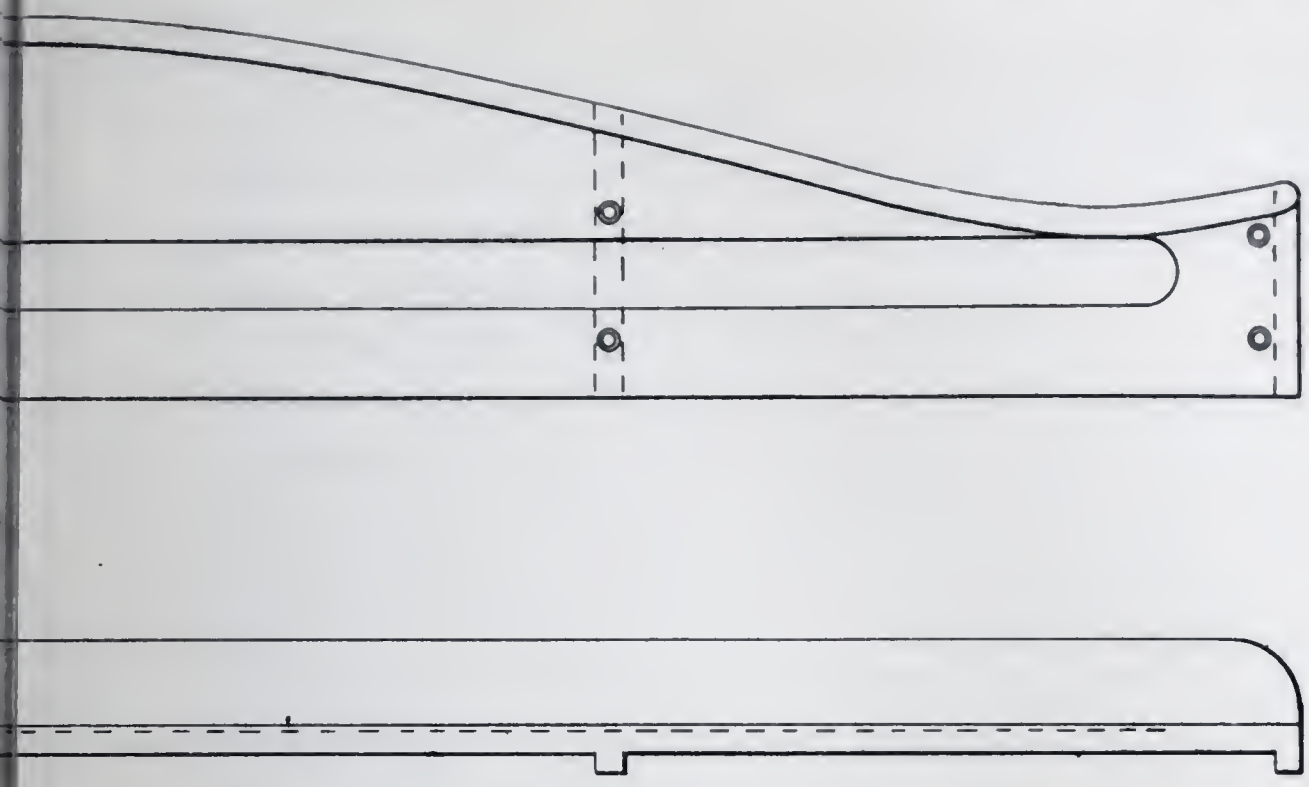
INCHES.

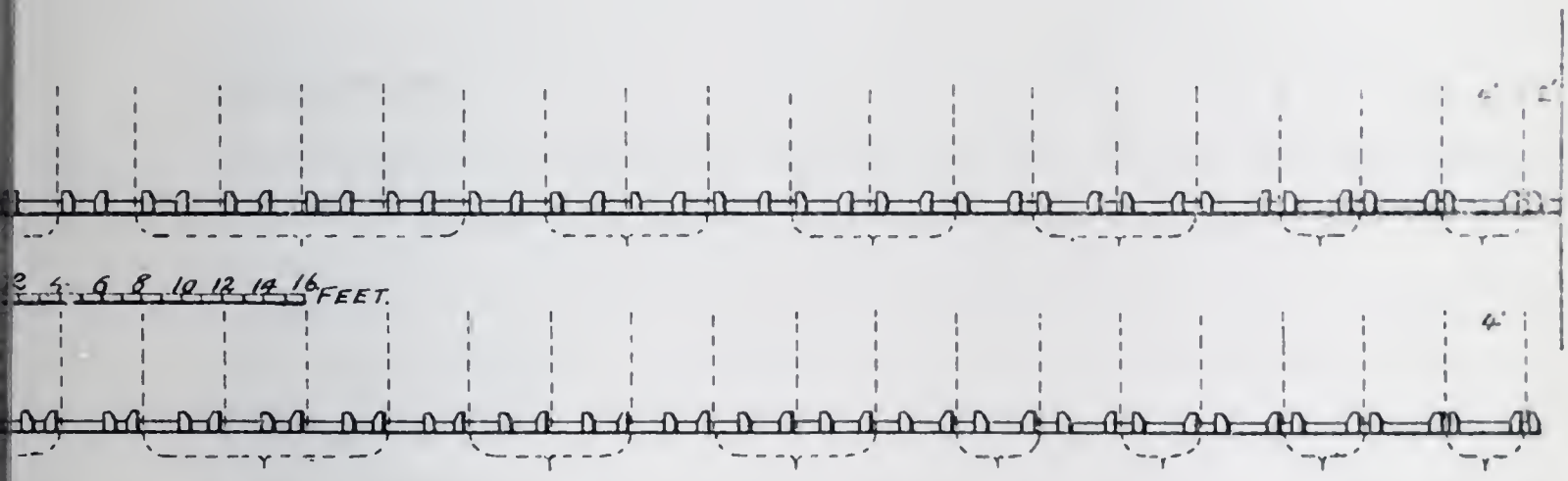


AVERAGE W.

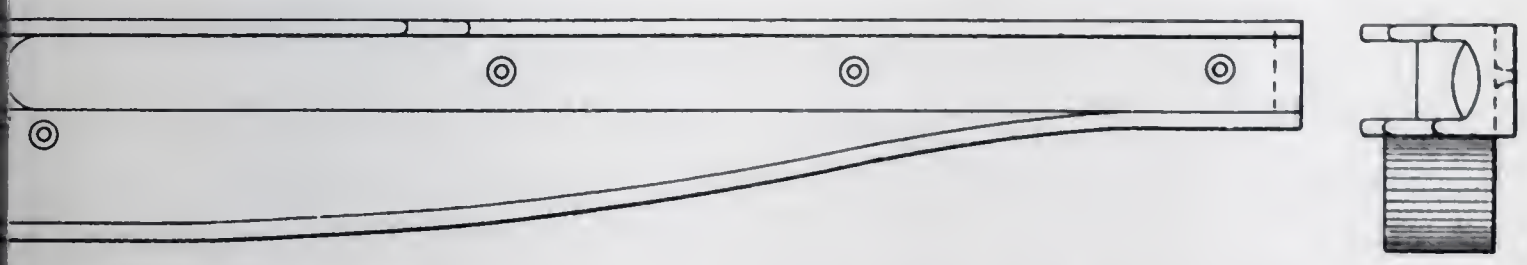
NOTE.

ALL OF THE ABOVE PARTS, WITH THE MACHINERY TO MANEUVER THEM, ARE NOW DISPLACED BY THE PASQUEAU HURTER ANNEXED.

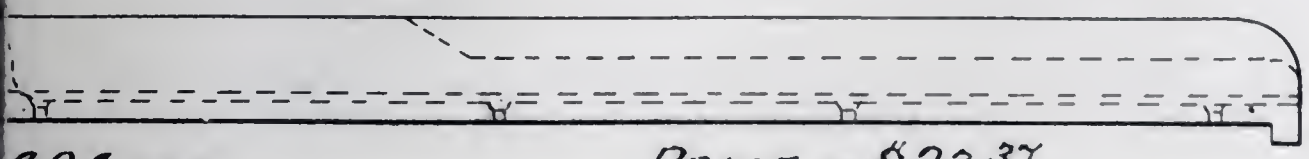




RIPPING BARS.



THE PASQUEAU DOUBLE-STEPPED HURTER.



494 LBS. PRICE = $23.37

and thrice in the lowering does it appear to have worked without accident or unusual delays. On the other eight occasions detentions were caused either by the wedging of the tripper-bar, or from the catches failing, pinions breaking, rack getting out of gear, or other defect in the mechanism.

These failures are doubtless largely due to the increased length of the passes and heights of the wickets, which have been found necessary to accommodate the large "tows" of our western rivers. The longest foreign pass, operated by Chanoine dams with tripping-bar, that I have been able to find recorded, is that at Melun, where the pass is 213.53 ft., with 50 wickets 9.51 ft. high. The longest *weir* is that at Le Coudray dam 229.93 ft., with 50 wickets 6.23 ft. high. This gives but 28.65 sq. ft. of surface on each of the 50 *weir* wickets, and 40.61 sq. ft. on each of the 50 pass wickets, exposed to pressure when the pool is full. At dam No. 5 on the Kanawha there are 62 pass wickets ($13' 9'' \times 3' 8''$) giving a pressure due to $50\frac{5}{12}$ sq. ft. on each of the props of the wickets, which is 25 per cent. more than that allowed in France. This pass was originally divided into two sections and operated by two trip-bars, one "about 142 ft. long," manœuvered from the lock wall, the other "about 120 ft. long" from the pier.

It is therefore evident that a system based upon this mechanism has but a limited application and is not well adapted to the requirements of *American* inland navigation, but the invention of the Pasqueau hurter was fortunately made just in time to be of great service, and its adoption by government engineers, already alluded to, has saved the system from numerous embarrassments and possible failure.

Concerning the use of the Pasqueau hurters at Lock and Dam No. 5, on the Kanawha,* Capt. Ruffner says, "it (the dam) was up from July 1st to Sept. 18th, 1881, when it was lowered for a rise." . . . (It was lowered in $2\frac{3}{4}$ hours by 7 men.) . . . "Preparations were made to raise Sept. 23d, 1881, when it was found that the lock section of the tripping-bar lacked about four inches of being back to place," etc. (The bar was broken in trying to force it

* Extract from Appendix G., Report of Capt. E. H. Ruffner to Col. Craighill—Report Chief of Engineers, p. 922, Vol. I., 1882.

out while off the guides). "Authority having already been given to try the Pasqueau hurters on a section of either dam 4 or 5, the broken bar was entirely removed, and measures taken to place the improved hurters on the whole section." . . . Three of the new hurters were placed last Fall. There are now 14 of the new hurters in. About two weeks more of comparatively low, clear water will be required to place the remaining 18." . . . "The Pasqueau hurters are adapted to the old *slides.*" . . . "It is hoped that the new hurters will turn out a decided improvement."*

Mr. A. M. Scott, Assistant Engineer, says :† "The dam has been up 111 days during the year (1882–83). The placing of the Pasqueau hurters on the lock section was completed Aug. 12th (1882), and the dam was entirely up on the 15th. . . . In lowering (Aug. 31st), the tripping-bar on the pier section refused to work, and the Pasqueau section was thrown first—the 34 wickets being lowered in 1 hour and 35 minutes (they have since been thrown, as reported below, in considerably less time). After this, the 28 pier-section wickets were lowered by winch and hook, pulling ahead at top from bridge, and tripping from boat below; whole time taken in lowering, 3 hours and 55 minutes."

(Thus the pass wickets, in deeper water, operated by the Pasqueau hurter were thrown in 2.8 minutes each, whilst the weir wickets, less than half the size, required, when thrown by hand, without use of tripping-bar, 8.4 minutes each.)

On Sept. 11th, an exceptionally heavy rain-fall required the lowering of the dam. "The order to begin was given by telephone at 9.40 A.M., and the lowering commenced at once on the lock (Pasqueau) section. These 34 wickets were thrown down with-without any trouble in 1 hour and 20 minutes. The water was rising so fast that with the 34 wickets down, it was nearly up to the top of those standing, and the "back lash" and "roll" below the dam were so bad that it was impracticable to *pull* the pier wickets down (the tripping-bar was out of order). The same was

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* The lock section of the tripping-bar, and 50 feet of the weir section were replaced by 46 Pasqueau hurters. The dam was up 121 days during the year.

† In the Report Chief of Eng., Part I, p. 712, 1883.

true of the wickets of the weir (they were all on the swing), and it was decided to lower the bridges, and leave the 28 pass and all the weir wickets up. The bridges went down all right and were out of the way at 1.30 P.M. The water reached its height (about 19½ feet above low water at lock) on the 13th, and fell so that the 28 pass wickets were lowered on the 16th. *No damage was done to either of the pass or weir wickets by the rise.* As stated, the 34 Pasqueau arranged wickets were thrown from the bridge in 80 minutes. (They have since been thrown in less time. In November, 23 of them were lowered, after the head had run down to about two feet, however, in 20 minutes.) . . . *It is apparent that even under these extraordinary circumstances, with Pasqueau hurters throughout, on both pass and weir, the whole dam could have been safely lowered after* 9.40, *with time to spare.* . . . The year's experience has demonstrated the successful working of the Pasqueau hurters and their decided superiority, particularly as applied to this river, over the tripping-bars. In fact, the advisability of avoiding the tripping-bars in future construction, and of getting rid of those already in use as soon as practicable, is considered well established."

Capt. F. A. Mahan, U. S. Corps of Engineers, who was for some years the principal assistant to Col. Merrill, in charge of the Davis Island Dam, has written a supplement to River Improvements in his father's work on Civil Engineering, in which he says (p. 519, edition 1884): "The trip-bar is the weakest feature of the Chanoine dam. The machinery to move it is more or less complicated, it is liable to get out of order, and if, for any reason, one wicket should refuse to go down, the movement of the bar is stopped, and the rest of the dam has to remain standing. By an arrangement of the hurter lately made, the trip-bar is done away with altogether. The hurter has two steps, the higher, which is the prop-seat, is made with a sort of pocket for the end of the prop to rest in, the lower has its down-stream face vertical, and making a very acute angle with the axis of the passage. The wicket is raised as in the ordinary system. The breech chain is pulled in until the prop falls into its seat. . . . The panel is righted by letting out the breech-chain slowly until the sill is touched.

"To lower the wicket it is first brought to the swing by raising

the breech. The motion is continued until the head of the horse is pulled up stream dragging the prop, which then falls down the second step, and is thus left without support. The inclined face of this second step directs the prop towards the passage of the hurter. The weight of the system carries it down, and the chain being paid out slowly prevents it from falling to the bottom with a shock. By means of this device each wicket is entirely isolated and independent. One of them failing to act will not cause any interference with the other, and even in the event of any difficulty, the absence of counter-catches makes it easy to knock down a prop from a skiff below the dam. A further advantage is that the navigable pass can be made of any width desired, which was not the case with the old trip-bar, because there the width of the pass could not exceed twice the length of a bar, one being manœuvered at each end."

He also shows "a longitudinal section and plan of Pasqueau's double seated hurter and slide," which has rendered it possible to construct so wide a pass as that used at the Davis Island Dam.

M. Pasqueau says with reference to the limit of play of the tripping-bar: "The tripping-bar must travel about six inches to trip a wicket 4 ft. 11 in. wide, including clearance. It follows therefore that the projections should be spaced 4 ft. 11 in., minus 6 in., that is about 53 inches apart, so as to lower the wickets in succession, and that with a single tripping-bar it is impossible to lower more than nine wickets in succession, since the eleventh projection strikes the tenth wicket at the same time that the first projection strikes the first wicket. It is true that 16 wickets can be lowered with one bar, by separating the projections into nine groups, so as to lower the first four wickets in succession; the next six in groups of two, and the last six in groups of three, but this extreme limit has not been exceeded, and it even seems that it cannot be reached at all without danger, in case the wickets are very high. As 16 wickets of 4 ft. 11 in. make 78 ft. 9 in. linear, two tripping-rods working in opposite directions must necessarily be used to close a pass $157\frac{1}{2}$ ft. wide, and it is not possible, with the system of lowering by tripping-bars, to make passes exceeding 160 feet without dividing them up by means of intermediate piers."

OHIO RIVER IMPR
MOVABLE DA

AS PROJECTED
(AT DAVIS ISLAN

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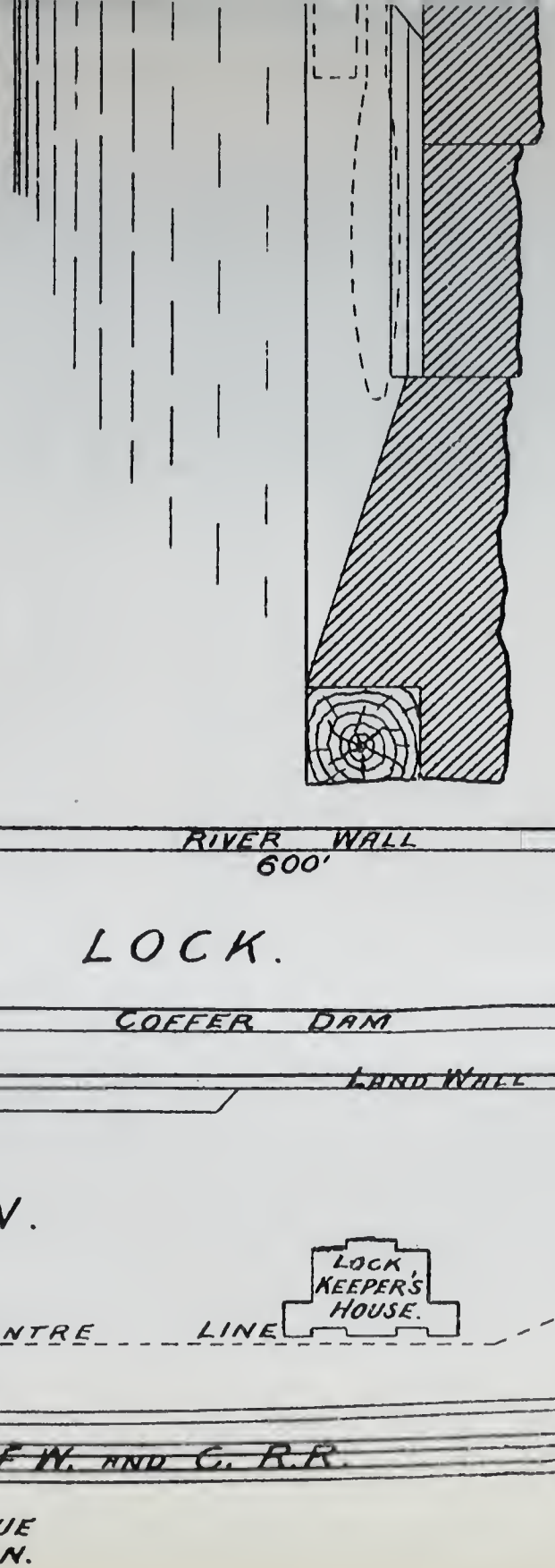

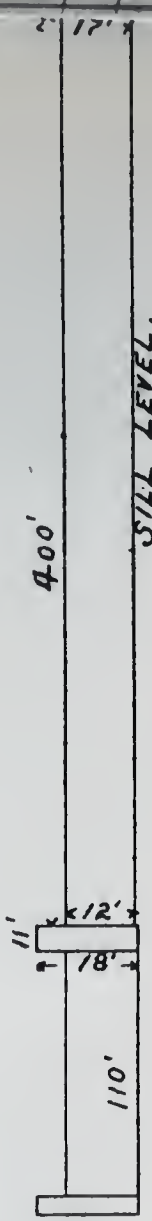

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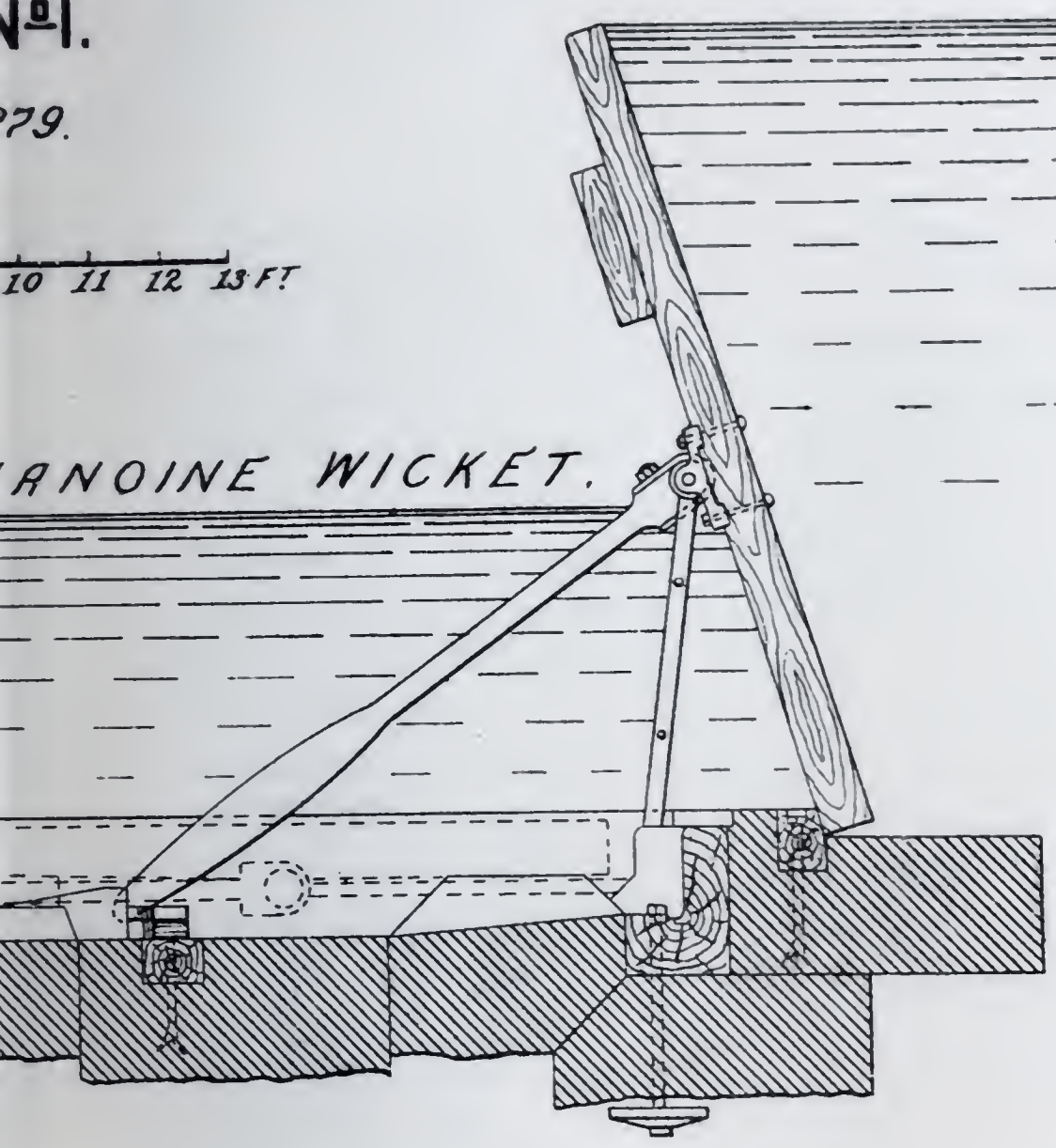
ANOINE WICKET.

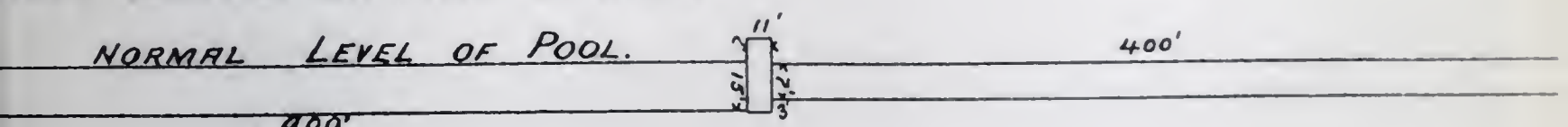


LINE OF DAM.

400' *400'*

LOW WEIR. *HIGH WEIR.*

ROSS SECTION ON LINE OF DAM.



"In France the largest bars do not exceed 30 metres (98 ft.), and this length is considered an extreme limit which cannot be exceeded. To reach it, it is even now necessary to violently knock down five or six wickets at a time."

The Tripper-bar at Davis Island Dam.

The designs for the Davis Island Dam, as shown to the members of the American Society of Civil Engineers and of this Club on the annual excursion to Cleveland in 1879, provided for a navigable pass of 400 ft. to be opened by tripping-bars. This width was the least that could be adopted, as the channel spans of the bridges on the Ohio were required by law to be 400 ft., and the boatmen even then complained that they were too narrow.* Anything less than this span would have been a serious obstruction to commerce not to be tolerated. So it was proposed to use two trip-bars, each over 200 ft. long, against which foreign engineers earnestly protested as being impracticable, and, in view of the experience with bars 142 and 120 ft. long on the Kanawha, and with those of 98 ft. in length abroad, it will be seen that the objections were well grounded, and the idea was finally abandoned in favor of the Pasqueau hurter. In short, but for this hurter the experiment at Davis Island would doubtless have been a failure, as the dangers and delays incident to lowering the wickets by tripping each prop by hand (the only other method then known for long passes) would have been too serious to have been entertained.

Even with the present wide pass of 559 ft., all open, a coal fleet was wrecked one dark night by striking the pier, which is a source of danger to all boatmen. In November of 1879, when the river was partially closed by a cofferdam, the steamer "George Lysle" ran her "tow" aground at the dam and sunk three barges, and subsequently the steamer "Dexter" collided with the sunken barges and sunk three more barges, almost entirely blockading the channel way. The damages were estimated at from $10,000 to $15,000

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* The middle chute on the Ohio at the Falls, 300 ft. wide, is found by experience to be too narrow, and its width is now being increased to 500 ft.

Concerning the use of movable dams in France, M. Malézieux, Inspector General of *Ponts et Chaussées*, writes from Paris, April 4th, 1879:*

"Leaving out of consideration the ancient systems (prior to 1830), there only remain among modern dams three classic systems which one may recommend without rashness: the Poirée, Chanoine and Desfontaines system.

"The Chanoine system of *swinging wickets* was greatly improved, almost at the outset, by the substitution of a *foot-bridge on trestles*, for a *manœuvering boat.* Among the improvements in details, which have since been made, there is none more important than the suppression of the *tripping-bar.* M. Pasqueau has proposed to replace it by what he calls a *double-stepped hurter.*"

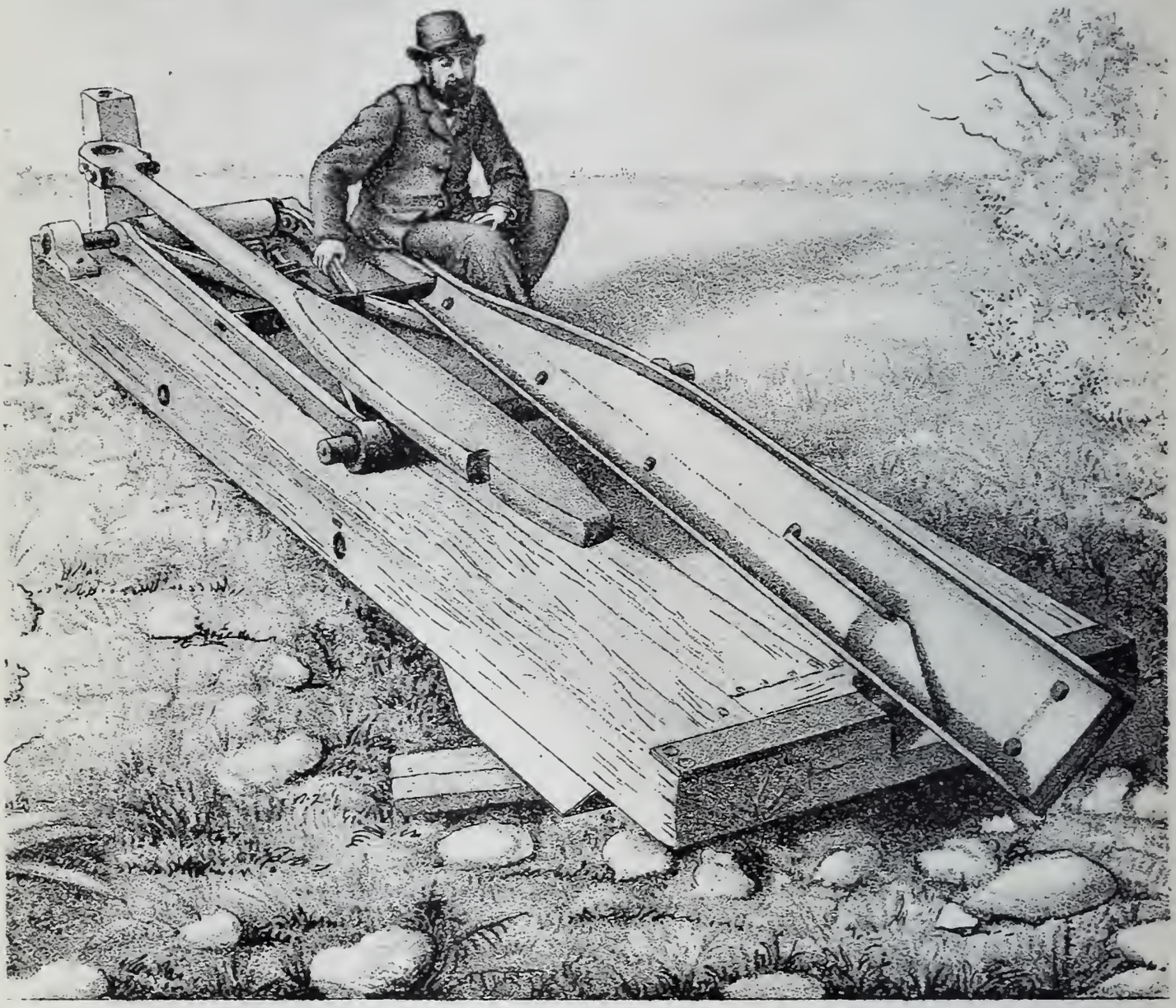
These hurters, with a traveling crane and other improvements, were put in at the dam known as La Mulatière at Lyons, where they are estimated to have effected a total saving in construction of 121,527.99 francs, or $24,305.60. Of this 55,371.63 was due to the hurter.

A pamphlet entitled "A New System of Movable Dams with Horses," recently published by S. Janicki, Director of the Moskva Navigation Company in Russia, was translated Sept. 24th, 1883, by Col. Merrill and submitted to the Chief of Engineers as a part of the literature of this subject. In this pamphlet the following tribute is paid to the invention of M. Pasqueau:

"In the latest application of the swinging wickets of M. Chanoine (at the La Mulatière dam at Lyons), Engineer Pasqueau, struck by the necessity of devising a new kind of movable dam which could be used for dams with high lifts and wide passes *without intermediate piers*, devised and applied an entirely novel arrangement, by which he could dispense with the tripper. Trippers, as is well known, are complicated pieces of mechanism, which practically limit the free opening between the piers of a dam to a maximum of about 50 metres (164 feet).

"The new arrangement of M. Pasqueau, which is very ingenious in its simplicity, consists in resting the props, which hold up the horses of the wickets, against a hurter and slide of a pe-

* R. C. of Eng., 1882, Part II, p. 1316.



DISMANTLED WICKET, HORSE AND PROP.

WITH THE

PASQUEAU HURTER,

AS USED AT THE

DAVIS ISLAND DAM.

culiar shape, which is fastened to the floor. This slide has two steps—the first supports the foot of the prop when the horse is upright; the other step is oblique and serves to push the prop sideways towards a horizontal groove, in which its foot can slide freely to the rear. . . . The double-stepped hurter of M. Pasqueau, against which rests the props of the wicket, permits the wicket to be raised, to be swung, and to be laid down, according to the necessities of the case, by a pull, which is always in one direction, and parallel to the thread of the stream. . . . The beautiful solution devised by Engineer Pasqueau for the La Mulatière dam, which is composed of Chanoine wickets with double-stepped hurters for props, and a service-bridge above for handling the wickets, has its justification in the local conditions due to the rapidity of the floods of the Rhone."

The accompanying illustration is taken from a photograph of one of these hurters as used at Davis Island. It is placed upon a dismantled wicket with its horse and prop, and tilted up so as to show the arrangement of the side flanges by their shadows.

This improvement may facetiously be called *a step in advance*, yet it is a vital step in the adaptation of the Chanoine system in this country, where the piers formerly required by the trip-bar system, with the dangers and delays incident to the use of such bars, would hazard the lives and property of those engaged in our river commerce and render it very expensive and unpopular, if not impracticable.

Manœuvering with Pasqueau Hurters.

As previously stated, the experience in manœuvering the dams at Nos. 4 and 5 on the Kanawha was very unsatisfactory, and as no reliable data are available for the comparison in this country, I quote from the report on the operation of the Pasqueau hurter at La Mulatière, as translated by Col. Merrill:

"From experiments made with wickets, the time for handling them should not exceed:

In lowering,	for one wicket,	3 minutes.
	" " trestle,	2 "
In raising,	" " wicket,	5 "
	" " trestle,	4 "

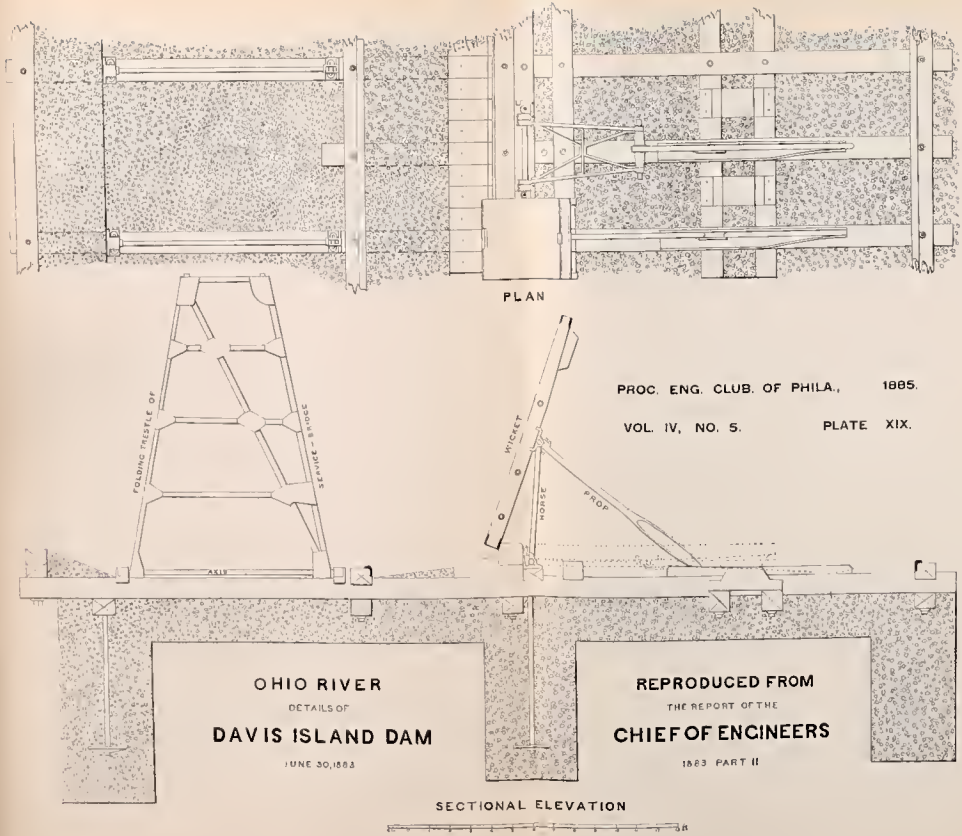
"That is, for a pass of 340 ft., containing 69 wickets and 34 trestles, worked by the same windlass: for lowering, 4 hours and 35 minutes, and for raising, 8 hours and 1 minute."

(These pass wickets are 14.3 x 4.6 ft.)

At Davis Island I was informed that at the trial of the dam, in manœuvering, three wickets were thrown in one minute and one wicket was raised in three minutes, which is much better time than that at La Mulatière. It is not possible, however, that this rate could be continued across the entire dam, and if we assume but one wicket per minute it would require about $7\frac{1}{2}$ hours for one corps to lower the pass and three weirs with their service bridges. It was intended to operate this dam from a traveling crane striding the wickets, and for this purpose the tracks for the traveler were laid with the floor of the dam, and the piers were shortened at the rear ends for its passage, but the plan was abandoned and the service bridge as used at La Mulatière was introduced. One of the most important improvements in this bridge consists in modifications by which the number of trestles is reduced to one-half that formerly used, thus not only saving material and workmanship in the original plant, but reducing the depth of the trough in which the trestles were laid when down, preventing the silting up of this channel by covering the trestles with their attached iron flooring, and greatly facilitating the manœuvers by reducing the number, without increasing their length for a given height of pool, as well as opposing less resistance to drift or ice when they are up, which gave so much trouble on the Kanawha.

Concerning this SERVICE BRIDGE at La Mulatière, Col. Merrill gives the following translation of the French report of Engineer Pasqueau, dated (Lyons, 1879*): "Up to the present time the trestles have been made to equal the wickets in number, and the *depth of the trench* necessary to shelter them when down has rapidly increased with the height of the bridge. At La Mulatière for a bridge raised 20 ft. above the sill this arrangement would require trestles $23\frac{1}{2}$ ft. high, lying six ranks deep and necessitating a trench 4 ft. in depth, which would have increased to in-

* Page 1753, Report of Chief of Engineers, Part II, 1880.



PROC. ENG. CLUB. OF PHILA., 1885.

VOL. IV, NO. 5. PLATE XIX.

OHIO RIVER

DETAILS OF

DAVIS ISLAND DAM

JUNE 30, 1883

REPRODUCED FROM

THE REPORT OF THE

CHIEF OF ENGINEERS

1883 PART II

tolerable proportions the danger of silting up and the difficulties of working. To avoid these inconveniences we have provided a *wide span service bridge*, placing the trestles 9.8 ft. apart and opposite the even numbered wickets. These trestles when down superpose in only three ranks, and thereby we have been enabled to reduce the depths of the trench to 28 in., to diminish the chance of silting up, to increase the rigidity of the trestle while at the same time diminishing the total weight of the bridge, and to reduce to 22.3 ft. the total height necessary in order to have the flooring 19.7 ft. above the sill." . . . (Then follows a description of the hinged flooring which saves time and labor in manœuvering, and serves as an apron for the trestles when laid in the trench.)

"In the ordinary trestle the upstream upright is vertical, and it is laid down lengthwise of a *vertical* chamber from 20 to 30 in. deep. When the dam is up gravel collects in this chamber and it is necessary . . . to remove the deposit by a diver every time the trestles have to be lowered. In our plan the trestles are symmetrical, their journal boxes are entirely in projection on the floor, and the latter is connected with the sill by a slope of one on two (one-half), which is less steep than the natural slope of sand deposits."

(These most important modifications of the Pasqueau system are shown in the last report of the Chief of Engineers, Part I, 1883, as having been adopted at Davis Island, where they have been successfully tried.)

The several features of this system may then be summed up as follows:

1. The water-way, or navigation pass, may be made of any length *without the use* of *intermediate* piers which are serious obstructions to navigation.

2. The dam may be built in sections of convenient lengths.

3. The complicated mechanism of the tripper-bar may be dispensed with and its cost be saved.

4. The wickets may be made much higher than when operated by trip-bars, and thus the number of dams in a continuous improvement be proportionately reduced.

5. The durability of the floor of the pass and of the wickets

themselves is greatly increased by preventing the shock caused by wickets 'tripped' under a considerable head of water; moreover, they may be made of metal instead of wood, and thus their life be extended greatly beyond the ordinary period of ten years.

6. Large dams may be worked rapidly, safely and surely, where if operated by trippers they would not be permissible.

7. The reduction of the number of trestles of the service bridge to one-half that formerly employed, resulting also in a reduction of their height, with corresponding economy in cost and weight.

8. A change of form of trestles, rendering them more readily handled and less liable to 'silt' up when laid in the trough.

9. A change in the form of trough from a rectangle to an open trapezoid, thus producing an automatic scouring and facilitating the certainty and economy of operation.

10. The further precaution against silting by covering the trestles with their *attached* folding floor, thus also preventing the great loss of time required in the old style service bridge to carry the flooring to the ends of the dam and store it away.

It will readily appear from this summary that even with unlimited means at command, there are many places where any system lacking these advantages would prove an entire failure, and that this would most frequently happen where the necessity for some improvement in navigation was greatest, as on large rivers having an extensive inland commerce and subjected to sudden floods and long droughts, such as characterize the Ohio with its fluctuations of 60 ft. and over. In fact it was due to the existence of the peculiar requirements at La Mulatière, which necessitated a pass of 340 ft., that led M. Alfred Pasqueau, after many attempts to solve the problem, involving much time and expense, to invent the present system, at once so simple, so effective, and so economical as to merit the award of the Legion of Honor from his government, and which has been so successfully introduced on our Western waters by the members of our United States Corps of Engineers under the supervision of Cols. Craighill and Merrill.

Cost and Benefits of this Improvement.

As the vital question in all innovations is, "Will it pay?" it

becomes necessary yet to consider the financial benefits resulting from the system of Chanoine-Pasqueau movable dams as adopted. Hence I do not intend to discuss their relative economy as compared with other systems, but merely their own costs and benefits.

The cost of the dam itself is as yet an uncertain quantity. In his Report to the Chief of Engineers, dated Sept. 1st, 1874, in discussing the subject, and when comparatively little was known, Col. Merrill had prepared plans for a lock 630 x 75 ft., with a lift of 6 ft., which he estimated to cost $200,000, and he adds: "The cost of movable dams will be

$344 per running ft. for the pass, and
227 " " " weir.

These estimates for the dams have been carefully prepared . . . by using the itemized bills of materials prepared from actual constructions in France, and are believed to be quite accurate. . . A movable dam of the average length of 1473 ft. will then cost as follows:

250 ft. of pass @ $344 per ft. . . .	$ 86,000
1273 " weir @ 227 " . . .	288,971
Total for one movable dam . .	$374,971
The cost of single lock with dam will be .	$574,971"

and for the 13 dams between Pittsburgh and Wheeling he makes the estimate $7,474,623.

These plans for a lock of only 75 ft. wide and pass of 250 ft. having been subsequently modified to remove the opposition of the boatmen, the estimates would be somewhat affected, though in widening the lock and reducing the total length of dam, there should be no very material difference in a work of this magnitude.

I have already shown that the appropriations for this work, including the estimate for this year, amount to $1,119,000, which is just about double the estimated cost of $574,971, made in 1874, and based upon French experience. Practical river men estimated the cost of each dam to be $1,000,000.

The Chamber of Commerce of Pittsburgh, in a pamphlet recently published,* refer to this work in these terms:

* The Mercantile, Manufacturing and Mining Interests of Pittsburgh, 1884.

"The completion of the Davis Island Dam, a work that has cost the United States Government nearly $800,000,* will give a pool of 7 ft. depth, of 1.62 sq. miles, sufficient to the harborage of over 12,000 steamboats and barges. . . . It is expected that harbor service boats for local towing will largely increase next season. The amount of hauling done from and between our mills is enormous, and a great economy of time and money can be effected by sending materials by river as soon as proper arrangements in the way of landings, etc., are made."

This $800,000, and the $110,000 estimated to finish, will bring the cost to nearly one million dollars, from which deduct, say $250,000, for lock and gates, and there remains for the movable dam of 1260 ft. and permanent dam, 456, total 1716 ft., a cost of $750,000, or $437 per lineal ft. That this would have cost even more but for the Pasqueau improvements is evident from the fact that all of them look to economy of construction, reduction of parts and simplicity.

The interest most benefited by the building of this dam are those of the boatmen in and around Pittsburgh. To form some idea of its pecuniary value to them, it will be sufficient to show the number of days of enforced idleness due to lack of water, and the value of the property thus affected.

In the reports of 1879 to the Chief of Engineers, Part II, page 1312, *et seq.*, Capt. Mahan summarized the observations on the discharges of the Ohio between 1855 and 1878 (24 years) in these words:

"The stages of the river are divided into three classes by those engaged in its navigation:

"1. The low-water navigation, or not less than 3 ft.

"2. The coal-barge stage, or not less than 6 ft.

"3. The coal-boat stage, or not less than 8 ft.

"The first is the lowest profitable stage for steamboats.

"During the 24 years ending December 31st, 1878, we find the following maxima, minima and averages:

Three foot navigation.	Average	duration of,	285	days.	
	Maximum	" "	364	"	in 1855.
	Minimum	" "	186	"	in 1871.

* Before completion.

Six foot navigation.	Average	duration of,	155	days.	
	Maximum	" "	212	"	in 1861.
	Minimum	" "	69	"	in 1872.
Eight foot navigation.	Average	" "	89	"	
	Maximum	" "	140	"	in 1864.
	Minimum	" "	25	"	in 1872."

Taking the average of these averages 285, 155 and 89, we have 176 days of navigation for vessels of average draft, and as the high water generally extends through the Winter season when navigation is interrupted by ice and other causes, the number of days available would be still further reduced. It will be within reasonable limits to put the average number of days interruption from ice per season at but 30, thus leaving 146 days available for navigation throughout the year, or 219 days of low water. This is just 60 per cent. of the entire year, during which time the capital invested in the boating interests is not only "tied up," but taxed by the necessary fixed charges to keep the property in repair and ready for use at the next "rise."

The value of this property, as given by the Report of the Pittsburgh Chamber of Commerce, is "4,323 vessels with a tonnage of 1,705,514 tons. Capital invested, $9,740,0000."

If then this capital nets 6 per cent. per annum, when idle 60 per cent of the time, it would be worth very much more to make it available every day of the year; thus the interest of $9,740,000 @ 6% is $584,400, which represents the income for 146 days use of the capital invested in boats. If they could run the whole year, the additional revenue at this rate would be $876,600, which represents a capital of $14,610,000. This amount would be greatly augmented by the direct benefits to the coal interests in which there is a capital of $25,000,000 invested.

In his reply to the "Statements of the Coal and River Trade in Opposition to the Davis Island Dam," dated Feb. 26th, 1879, and addressed to Hon. Stanley Matthews, Col. Merrill says, with reference to the stages of water (page 3): "The fact is that a careful compilation of 22 years' gauge operations at Pittsburgh shows that there is an average of 156 days, or five months, of 6 ft. navigation. But even this amount is dependent on rises, and it cannot be foreseen when these rises will come nor how long they

will last. In 1871 there was less than 6 ft. in the channel at Pittsburgh from the 15th of May to the 15th of November, a period of 6 months. During this time a steamboat, whose name I cannot recall, lay at the wharf at Pittsburgh, loaded, among other things, with agricultural implements. After some months of waiting, and much injury to her deck cargo by the action of the sun, she was unloaded, her freight was shipped by rail, and the boat sold by the sheriff. It is precisely this uncertainty of navigable water that makes an improvement so necessary."*

In fact, so thoroughly convinced are the boatmen of Pittsburgh of the value of the improvement, that one of them recently wrote that it was worth $1,000 per week to him to have the Davis Island Dam up. The river men, formerly its most bitter opponents, are now its most enthusiastic admirers.

"It has been estimated by Col. Long, that the western rivers afford a development of 16,674 miles of steamboat navigation, while the commerce of these rivers for the year 1843, . . . possessed a value of more than $220,000,000."†

In 1869 Col. W. Milnor Roberts caused to be compiled as accurate a statement of the value of Ohio River commerce as could be obtained, and he concluded that its annual value was $694,000,000;"‡ and again in 1874, in a report to the Government, Col. Roberts estimated "the river trade of each city, town and landing along the thousand miles between Pittsburgh and the mouth of the Ohio," at over $800,000,000. In other words, the river trade equaled the total foreign commerce of the United States, and political economists estimate home trade to be worth double that of equal amount with foreign countries.§

The greatest distance traveled by a Pittsburgh steamer was to Cow Island, on the Upper Missouri, a distance equal to 4,300 miles, which is as far as from New York to the Baltic or Mediterranean. At present more than 20,000 miles of inland navigation are open to the vessels of Pittsburgh in favorable seasons. A single steamboat has conveyed a tow of 20,000 tons of coal down

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* In 1856 there was less than 6 ft. from May 24th to December 4th, a period of 6½ months. Since completion, Dam No. 4 on the Kanawha has been up 42 per cent., and No. 5, 34 per cent. of the whole time, including the winter months.

† Ellet on the Mississippi and Ohio Rivers, pages 307 et seq.

‡ Reports Chief of Engineers.

§ Vide Report Pittsburgh Chamber of Commerce, p. 79.

the river. This is a cargo greater than any ever handled by the Great Eastern.

In his argument in favor of the improvement of the Ohio River, Major Ellet further says:

"The navigation of all streams bearing this vast and rapidly increasing commerce is interrupted during *more than one-third of the year*, by the want of water, or by ice, which accumulates to an injurious extent because of the want of water.* This interruption is equivalent in its effects to an annual tax upon the industry of the country equal to one-third the yearly expense of maintaining all the steamboats that are subject to the detention, together with the value of the delay upon all the property that is exposed and detained, and that of the deterioration and early destruction of all the boats that are compelled to run when there is too little water to float them safely. The number of boats navigating the western rivers is at this time (1848) not less than 1,000, and it is estimated . . . that the total loss from wrecks of steamboats on these waters for the year 1848 alone, amounted to $2,000,000."

In the Report for 1882,† Col. Merrill gives a tabular statement of losses due to bridge piers in the Ohio. "The table is as complete as it is practicable to make it, but there is good reason to believe that many cases of loss have escaped our search." . . . This table would be more valuable if it contained the number and position of the piers. It is headed: "*Revised List of Losses by Collision with Piers, etc., of Ohio River Bridges. Compiled June 30th*, 1882." (I quote only the totals.)

Beaver	*Bridge*, completed in 1878, losses to date, .	$ 28,587
Steubenville	" " " 1863, " " .	69,556
	(One wreck, Dec. 2d, 1869, of seven barges; loss, $17,638.)	
Bellaire	*Bridge*, completed in 1871, . . .	116,745
Parkersburg	" " " 1871, (and 4 lives lost),	55,000
Newport & Cin.	" " " 1872, . . .	34,625
Cinn. Southern	" " " 1877, . . .	9,812
Louisville	" " " 1871, . . .	70,600
Total, ...		$384,925

* Gen. Weitzel in reporting on the canal around the Falls of the Ohio, says: "Canal in use only about one-half the time, in consequence of high water, ice and low water."—(From June, 1874 to 1882, inclusive.)

† Report Chief of Engineers, Part III, 1882, p. 1926.

"Some of these wrecks occurred during construction. I have therefore taken the average *annual* loss for each bridge, and find the aggregate of these losses to the boating interest on the river, between 1862 and 1882, to be very nearly $32,500. These are only the losses reported between Louisville and Pittsburgh. They represent a capital of $541,666, which it would therefore pay to expend annually to avoid them if possible."

Maj. Ellet continues: "There are no data for determining the loss consequent upon the detention of the boats; * but as the delay falls chiefly upon the largest steamers, which are always first arrested, the loss must greatly exceed the actual cost of maintaining and retaining 750 boats one-third of the year or 250 boats of average value the whole year, it will amount to not less than $3,000,000 per annum † over and above the loss now sustained on the property conveyed, and that on the commerce which cannot be conveyed.

By upholding the draft in the channel, the cost of transportation, which now fluctuates between 8 cents and $1.75 per hundred pounds, from Pittsburgh to Cincinnati, could be maintained, with profit to the carrier, at about the lowest present charge, and the whole business of the valley would experience a corresponding increase, consequent on the reduction of the cost of freight. A vastly increased tonnage would necessarily be conveyed at greatly reduced rates. The business of the transporter would become more certain and more stable. . . . . It is scarcely to be doubted that the maintenance of a depth of 5 ft., in the Ohio alone, at all seasons would save the country from an *annual* tax upon its present business of $5,000,000 or about eight times the sum necessary to produce the saving."

The total revenue collections in 1881 for the eight States which wholly or in part lie in the Ohio basin were $87,500,000, and the increase of the registered undertonnage ‡ of the Ohio alone from 1875 to 1881 has been 48½ per cent. § The total revenue collec-

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* Gen. Weitzel estimates the cost of delay to the Ohio River passenger steamboats at $200 per day, vide p. 1900, Report Chief of Engineers, 1882, Part II.

† This is $33 per day for each boat, or but one-sixth of Gen. Weitzel's estimate.

‡ About one-half the actual tonnage.

§ Gen. Weitzel to Chief of Engineers, 1882, Part II, p. 1899.

tions for the whole country were $135,000,000, of which nearly two-thirds were contributed by these States.

Thus it will be seen that the territory affected by the improvement of the Ohio is that tributary to 20,000 miles of inland navigation, having a commerce of greater value than the foreign commerce of the entire United States and producing, under the present comparatively unimproved condition of its river, two-thirds the revenue of the whole country. It is a well-recognized fact that cheap and certain transportation is one of the most important elements in promoting the welfare of the people, and developing the material resources of the country, and that there is no transportation that can compare in cheapness with that by water if it can be made reliable at all seasons.

By the Pasqueau-Chanoine system, as now used by the Government, all of these benefits may be secured to it, and the problem of the future navigation of our western rivers, with safety, certainty and despatch, may be considered satisfactorily solved.

SUPPLEMENT.

Historical Sketch of the Work of the United States in the Improvement of the Ohio River.

Prepared by Col. Wm. E. Merrill, U. S. Corps of Engineers.
In charge of the improvement of the Ohio River, etc., etc.

On the 27th of January, 1817, the General Assembly of the State of Ohio, by joint resolution, requested the States of Pennsylvania, Virginia, Kentucky and Indiana, to unite with Ohio in appointing Commissioners to examine the Ohio River, and submit a report of its condition, and the amount of money required to improve its navigation. A special examination was to be made at the Falls of the Ohio, at Louisville, in order to determine upon the best method of passing these Falls by canal or otherwise, and, in case a canal was decided upon, to select the side on which it

should be built. At the same time the Senators and Representatives in Congress, from Ohio, were requested "to use their best endeavors in the event of the creation of a fund for internal improvements, to procure a portion thereof for the above purpose."

These propositions from Ohio were accepted by Pennsylvania, Virginia and Kentucky, and the four Commissioners thus appointed made a report, which is dated Nov. 2d, 1819. They gave sketches of all the bars between Pittsburgh and Louisville, with the depth and fall at each bar, and a map and cross-section of the Falls, at Louisville, with two routes for a lateral canal; they gave their preference to the route on the Kentucky side. They estimated the cost of a suitable canal at Louisville, at $380,594, and recommended an appropriation of $10,000, by each of the four States, for use on the river at large. No action was taken by the States on this report.

The first appropriation by Congress was made in 1820, for a survey from Louisville to Belize (the mouth of the Mississippi). This survey was made in 1821, by Capts. Young and Poussin, of the Topographical Engineers, and Lieut. Tuttle, of the Engineers. It gave a continuous outline plat of the Ohio River, from Louisville to its mouth, and of the Mississippi River from St. Louis to New Orleans.

The first appropriation by Congress for the improvement of the Ohio, was one of $75,000, made in 1824, for the improvement of certain sand bars in the Ohio River, and for the removal of snags from the Ohio River, and from the Mississippi River from the mouth of the Missouri to New Orleans. The President was directed to take any two of the following bars in the Ohio River, viz.: Flint Island, French Island, Henderson, Straight Island, Willow Island, and lower Smithland, for experiment; and, in case of success, he was authorized to undertake work on the others.

The first dike on the Ohio River was begun in 1825, at Henderson Bar, under the personal direction of Major S. H. Long, Topographical Engineers. The removal of the rocks at the Grand Chain was begun in 1830. Dikes were begun at Scuffletown and The Sisters in 1831, and at French and Cumberland Islands in 1832.

No work except the removal of snags, was done on the Ohio above Louisville until 1836, when the dams at Brown's Island were begun. The success of these works was such that a very large number of dams and dikes were subsequently built between Pittsburgh and Cincinnati, from this time until the general stoppage of work in 1845.

From 1827 to 1844, inclusive, there were annual appropriations for the improvement of the Ohio River—sometimes alone, and sometimes in conjunction with Mississippi, Missouri or Arkansas.

In 1845 the policy of the Government changed, and except about $500 in 1847, and $150,000 in 1852, for the four great Western rivers, there were no further appropriations until 1866. Since the latter date an appropriation for the improvement of the Ohio River has been made in every year except 1869, 1877 and 1883.

In 1850 Mr. Charles Ellet, Jr., a civil engineer employed at Wheeling in the construction of a suspension bridge, sent a memorial to Congress recommending the improvement of navigation on the Ohio River by building large reservoirs on the upper sections of the various tributaries, with the intent of letting out the accumulated supply during seasons of low water. No action was taken by Congress on this plan, and both Mr. W. Milnor Roberts and Col. W. E. Merrill, who, between them, have had charge of the improvement of the Ohio River since 1866, have reported that the scheme is impracticable.

Mr. Ellet's paper was printed in 1850 by the Smithsonian Institution, in the second volume of the Smithsonian Contributions to Knowledge.

The following list shows all of the dikes and dams that have been built on the Ohio up to date:

Rip-rap and Crib Dams and Dikes in Ohio River.

Miles Below Pitts-burgh.	Place.	Work Done.
2	Duck Chute.	Dam built in 1873.
2½	Glass-house.	Dike built in 1871 and 1872.
3	Chartiers Creek.	Dam built in 1871, 1872, 1873.
5	Davis Island.	Dam partly built in 1844.
5½	Neville Island.	Dam partly built in 1844.
8	Duff's.	Small dike built in 1844.
11	Foot of Neville Island.	Dam built in 1877.
11 to 12	Whites and The Trap.	Dikes and cross-dam partly built in 1838 and 1839. Repaired in 1844 and 1867. Rebuilt in 1876, 1877, 1878. Repaired in 1883.
19	Logstown.	Dikes built in 1867, 1868.
27	Beaver Shoals.	Dike built in 1870.
50	Baker's Island.	Dam partly built in 1844.
54	Black's Island.	Dam partly built in 1844.
61	Brown's Island.	Curved wing dam built in 1836, 1837. Dam at head built in 1837, 1838. Rebuilt in 1881, 1882, 1883. Repaired in 1884.
70	Mingo Island.	Dam built in 1844.
78	Beach Bottom.	Dam partly built in 1844.
84	Twin Islands.	Dam partly built in 1844. Completed in 1867, 1869, 1871, 1872. Dike at foot of upper Twin built in 1871, 1872.
89	Wheeling Island.	Dam built in 1869, 1872, 1873.
107	Captina Island.	Dam built in 1844. Repaired in 1854, 1867, 1869.
112	Fish Creek Island.	Dam partly built in 1844. Repaired in 1867, 1868, 1869.
128	Fishing Creek.	Dam built in 1844.
133	Williamson's Island.	Dam partly built in 1844 across left channel, and small dam built at foot of island.
138	Well's Island.	Dam partly built in 1844.
140	Mill Creek Island.	Dam partly built in 1844.
141	Grand View Island.	Dam partly built in 1844.
143	Grand View Shoals.	Dike built in 1869.
146	Shift-tail Ripple.	Dike built in 1869.
147	Petticoat.	Dike partly built in 1844. Repaired in 1867.
157	Three Brothers' Islands.	Dam partly built in 1844 to head of second island.
168	Marietta Island.	Dam at head built in 1871, 1872, 1873, Dike at foot of island built in 1844. Rebuilt in 1875.
174	Muskingum Island.	Dam commenced in 1844. Repaired and finished in 1868.
180	Cole's Island.	Dam partly built in 1844.
185	Blannerhasset's Island.	Dam at head built in 1844. Repaired in 1867, 1868. Dike at foot of towhead and wing dam built in 1867, 1868, 1869.
193	Newberry.	Dam partly built in 1844.
202	Belleville Island.	Dam partly built in 1844. Dike to middle bar and dike at foot of same built in 1844. Repaired in 1869.
214	Buffington.	Curved wing dam in left channel built in 1844. Repaired in 1867, 1873. Spur dike built in 1868, and removed in 1873. Dam at head built in 1867, 1868, 1869, 1873.

Miles Below Pitts-burgh.	Place.	Work Done.
232	Letart's Island.	Dam built in 1844.
237	Raccoon Island.	Dam built in 1844.
312	Twelve Pole.	Dike built in 1881, 1882, 1883.
385	Brush Creek Island.	Dam partly built in 1844.
457	Four Mile.	Upper dike built in 1879, 1880. Lower dike built in 1880, 1881.
485	Medoc.	Dike built in 1870, 1871.
501	Rising Sun.	Dike built in 1870.
525	Warsaw.	Dike built in 1870.
581	Grassy Flats.	Dike partly built in 1844.
601	Sand Island.	Dam built in 1871.
603	Portland.	Dike built in 1881, 1882, 1883.
743	Puppy Creek.	Dike built in 1881, 1882, 1883.
758	French Island.	Dikes at foot of island built in 1832. Kentucky dike rebuilt and island dike repaired in 1873, 1874, 1875. Repaired in 1878, 1879.
767	Scuffletown.	Dikes built in 1832.
770	Three Mile Island.	Dike built in 1833, 1834.
783	Evansville.	Dike built in 1873, 1874, 1875, 1876, 1878, 1879.
796	Henderson Island.	Dam across Kentucky channel built in 1873, 1874, 1875. Dike built in 1824, 1825. Rebuilt in 1873, 1874, 1875. Dam and dike repaired in 1879.
893	Sisters.	Dikes built in 1832.
907	Cumberland Island.	Dam begun in 1832 and partly finished. Repaired in 1839, 1854. Repaired and completed in 1872, 1873, 1874.
943 to 948	Grand Chain.	Upper dike built in 1879, 1880, 1881, 1882, 1883, 1884. Lower dike built in 1880, 1881, 1882, 1883.

Movable Dams.

The attention of American engineers was first called to the subject of *movable dams*, by the publication of a report, dated January 31st, 1874, of a Board of Engineer Officers, consisting of Gen. G. Weitzel and Col. W. E. Merrill, on the subject of movable hydraulic gates. To this was added a second report, dated Nov. 24th, 1874, containing additional information, and both reports were subsequently printed for general distribution, as Executive Document No. 78, H. of R., 43d Congress, 2d Session.

The actual construction of a movable dam on an American river, was first recommended by Col. W. E. Merrill, Corps of Engineers, in his Annual Report, dated Sept. 1st, 1874. In accordance with this recommendation, Congress, at its next session, appropriated $300,000 for the improvement of the Ohio River, and

provided "that $100,000 of this amount shall be used for and applied towards the construction of a 'movable dam,' or a dam with adjustable gates, for the purpose of testing substantially the best method of improving permanently the navigation of the Ohio River and its tributaries." This allotment was contained in the River and Harbor Act of March 3d, 1875.

A Board of Engineers, consisting of Generals Wright, Weitzel and Poe, and Colonel Merrill, was appointed to select a site for the proposed movable dam, and in their report, dated April 19th, 1875, they selected the site at Davis Island.

The work of construction was kept back by the difficulty of getting through the Legislature of the State of Pennsylvania, a cession of jurisdiction to the land required for the lock and dam.

In anticipation of the construction on the Ohio River of dams of some kind, efforts had been made as early as 1873 to secure from the State of Pennsylvania a general cession of jurisdiction over land required for such purposes, and a bill granting the necessary cession passed both Houses of the State Legislature, during the session of 1873–4, but it was vetoed by the Governor on technical grounds. During the session of 1874–5 a new bill, prepared to meet the objections of the Governor, passed one House, but was mislaid in the other, and failed to become a law.

In the session of 1875–6, another effort was made to obtain cession of jurisdiction from Pennsylvania; but this time the failure was due to the opposition of the coal shippers of Pittsburgh, who had become hostile to the proposed movable dam. A bill granting the required cession of jurisdiction, and authorizing the condemnation of the necessary land, was finally passed on the 17th of March, 1877.

A little more than a year was consumed in the legal delays incident to obtaining possession of the required tracts of land, and thus work was not begun on the Davis Island Dam until August 19th, 1878. Various causes of delay, such as are incident to all government work, have since intervened from time to time, so that the work is not yet finished; but it will certainly be completed in 1885.

In the latter part of 1877 the Engineer in charge submitted plans for changing the interior dimensions of the lock from 630

by 78 feet, to 600 by 110 feet, substituting single rolling gates for the customary pair of mitre gates. A Board of Engineers having reported favorably, the change was approved on February 9th, 1878, by the Secretary of War.

On the 9th of August, 1880, the Engineer in charge suggested that a Board of Engineers be appointed, to consider additional modifications in the Davis Island Dam. This Board consisted of Col. Craighill, Gen. Weitzel, Col. Merrill, and Lieutenants Turtle and Mahan. Col. Merrill called the attention of the Board to the Pasqueau hurter, and recommended that it be used on the Davis Island Dam instead of the tripper; he also recommended that the Dam be so built as to permit experiments with a straddling traveler, with a view to the ultimate suppression of the foot-bridge. The Board reported favorably, and recommended that experiments with the Pasqueau hurter should meanwhile be tried on the Kanawha dams, which were then finished. The views of the Board were concurred in by the Chief of Engineers, and the use of the Pasqueau hurter was formally authorized by the Chief of Engineers, under date of March 25th, 1881. A contract for iron work for the navigable pass of the Davis Island Dam was signed on the 24th of May, 1881, and in this contract were 141 cast iron Pasqueau hurters.

During the summer of 1884 the Davis Island Dam was up for five weeks, and its effect on the harbor of Pittsburgh was so satisfactory, that after it had been lowered on account of a rise, several urgent appeals were made by coal shippers to have it raised again, in order to bring their barges out of the pools of the Monongahela. As compliance with this request would have necessitated the closure of the lock by a temporary coffer dam, and for other reasons, the Engineer in charge was very unwilling to accede to their wishes, but the pressure became so great, that he finally telegraphed an order for the raising of the Dam. Fortunately an opportune rise in the river made it unnecessary to obey the order.

The total expenditures on the Davis Island Dam to the close of 1884, have been as follows:

Years.	Expenditures.
1875	$ 154 75
1877	324 74
1878	105,675 17
1879	211,340 89
1880	82,217 16
1881	179,813 70
1882	155,458 11
1883	93,631 30
1884	29,637 02
Total,	$858,252 85

The total cost of the Dam will be less than $900,000.

Thus far the following movable dams have been built, or are building, in the United States, by the Government.

On the *Great Kanawha River*, Dams Nos. 4 and 5 were completed in 1880, and No. 6 is building. The first two are on the Chanoine system, with tripper; No. 6 will be on the Chanoine system with Pasqueau hurter.

On the *Ohio River*, the Davis Island Dam is on the Chanoine system with Pasqueau hurter; it will be finished in 1885. At the head of the Falls, at Louisville, there is a fixed dam with two openings, one for the Indiana Chute, and one for the Middle Chute. In the former there is a section of Boulé movable dam, 160 feet long, which was built in 1883; in the latter there is a Boulé movable dam 300 feet long, built in 1880, with an extension of 200 feet, built in 1883. In the guiding dike there is an 80-foot Thénard movable dam, built in 1881 and re-built on a new site in 1883.

On the *Upper Fox River, of Wisconsin*, there is a small movable dam, which is a combination of the Boulé and the Tavernier systems; it was built in 1877.

On the *St. Mary's Canal*, there is a Pasqueau-Tavernier movable dam for use in case of accident; it was built in 1881.

XXII.

ENGLISH CENTRIFUGAL PUMPS.

By Edw. J. H. Howell, Member of the Club.

Read December 6th, 1884.

So long as English and American mechanical methods vary so materially, it must always be interesting and instructive to compare the practice of the two countries, as it may bear upon any particular machine; and the centrifugal pump, so highly developed and esteemed by our "kin across the seas," is probably one of the best types to study.

To an English engineer (the late John G. Appold), we are indebted for the centrifugal pump. After spending a fortune in perfecting it, he generously refrained from patenting his invention, and gave the world the benefit of the labors of the best years of his life.

From a crude water fan, returning only 12 per cent. of effective work for power expended, he developed a machine capable, under certain conditions, of increasing this result to more than 75 per cent. of effective work.

Since Appold's death in 1865, some of the ablest engineers have given their attention to this type of pump; and the same scientific study bestowed with us on the direct acting or duplex pump, has in England been devoted to the centrifugal.

There are probably eight or ten English builders of centrifugals for the market, and of these two or three of the first rank as mechanics—men whose names have a world-wide reputation.

The competition between these builders is much the same as that of our leading steam-pump makers; all strive for the highest results in construction efficiency and economy.

These pumps are beautiful in design to the eye of a mechanic, models of strength and simplicity; the English love for solid weight is well exemplified in these machines, and the extra metal does not seem amiss, when the high speeds at which the pistons must run are considered.

The bearings are long and fitted with gun metal boxes with

self-oiling arrangements, pistons balanced, and with spindles of steel, large and perfectly true, and the details of construction generally, such as we put on a high speed steam engine.

The curvatures of shell or piston, and the shape and size of water passages, are carefully studied and varied to suit the work to be done, all being based upon scientific research and practical experience.

The means of priming used by English builders are neat and effective; some have the steam jet, others employ a little air exhauster driven from pump-shaft, and contained within pump.

Foot valves are rarely used, but a flap valve on delivery pipe is preferred, whenever possible.

The result of all this care and experience is a machine which for certain duties is unsurpassed, and is available for many uses for which we now think the steam pump necessary.

In efficiency and economy nothing can compare with the centrifugal, where large amounts of water are to be raised to a slight height and in a short period of time—the more so as dirty or gritty liquids are equally well handled.

All over the world will be found these English machines: in China, Japan and India, irrigating fields in the rice, indigo, and cotton districts; in the Nile valley, pumping thousands of tons from the river, while the creaking wheel draws its weary buckets alongside; in Holland, where hundreds are at work holding back the sea; in the great European cities, pumping sewage or emptying graving docks; and all over the world in steamships and wrecking-vessels, everywhere proving their value as efficient and economical machines.

Single pumps capable of raising eighteen to twenty-five thousand gallons per minute, from five to ten feet, are frequently built. These giants among pumps stand from eight to twelve feet high, and have discharge outlets of from thirty to forty inches diameter.

The present English practice, however, favors a number of smaller pumps arranged to be driven together, rather than one very large machine.

The usual pump is that driven by a belt, but numerous styles are built, in which one or more pumps are driven directly by

high speed engines attached to the spindle of the piston; this design is largely used for circulating and bilge pumps for steamships, as well as for drainage and wrecking pumps.

The variety and ingenuity of arrangements to make the centrifugal pump available for all uses (both on a large and small scale) is very great, and form an interesting study.

At the Exposition of 1876, a model was shown of one of the largest pumping plants ever made, known as the Ferrara pumping works, for draining the marshes near the city of the same name in Italy.

The system comprised a series of centrifugal pumps, arranged to be driven by compound surface condensing engines of 2,400 horse power, capable of raising to a slight elevation one-half a million gallons of water per minute. This machinery frequently has run three or four months, and on one occasion five months without stopping; and after ten years' use has proved efficient and inexpensive, and is claimed by the makers to be the most economical pumping plant ever erected.

In Holland, many smaller centrifugal pumping works, of from ten to one hundred thousand gallons per minute, are in use with good results, both as regards efficiency and economy.

In graving and dry docks this class of pump has given excellent results. The official report of engineers in charge of a dock at Greenock, Scotland, state that the dock which is 660 feet long, 175 feet wide, and containing 30,000 tons of water, is emptied by a pair of 24-inch Gwynne pumps, driven by two direct acting engines, in $2\frac{1}{2}$ hours, at a total cost of 10s. 8d., including all expenses.

As bilge and circulating pumps for surface condensers, the English centrifugals are firmly established in favor, and will be found on most of the new Atlantic fast ships, as well as on many others built by the great shipbuilding firms on the Clyde.

Thus for more than thirty years, English engineers have experimented with the centrifugal; their mechanical literature contains the drawings and results of costly experiments and years of experience; innumerable variations in design and construction have been tried, and from these labors of many men the present English model is evolved, undoubtedly the embodiment of all hat practice and science have shown to be correct

With all this experience to study, and with the details of every step readily accessible, how have American pump-builders profited by it? To all but a very few, the English practice, and the principles of construction established by it, are apparently unknown; and of the few builders whose pumps show any degree of value, only one or two endeavor apparently, to embody the established principles of centrifugal practice.

Compared with the best English makers, American centrifugals will be found wanting in all points in design, construction and workmanship; and in variety of style, and arrangements for various uses, we are far behind the English practice.

The field in America for the centrifugal type of pump is broad, and as yet hardly occupied, and we await the builder who will intelligently study and carefully construct, centrifugals which shall embody the best that English experience has established, with the addition of American ideas and adaptability.

XXIII.

THE FUTURE OF LOCOMOTIVE BUILDING.

By George S. Strong, Member of the Club.

Read December 20th, 1884.

In considering this subject, we shall first inquire into the drift of the times towards heavier locomotives and higher pressures necessitated by increasing traffic and the demands for faster train service between the large cities, not only in this country but in England and on the Continent of Europe. Then we shall endeavor to see how these demands will most likely be met in the near future; and in doing so, we will have to examine the present locomotive as it is, by analysis, *i. e.*, in its several parts, to find where its defects are and what will probably be the remedies applied.

Fast Passenger Express Trains in England.

Express trains, says the author of two brilliant essays on this subject, recently published in England, are *par excellence* the expression of English nature.

There are fourteen (14) English companies, we find, which run express trains, including in that term all trains which have a journey speed, counting stoppages, of forty (40) miles an hour and upwards. The daily number of such trains is about 313, of which no fewer than 52 run between Manchester and Liverpool. Beginning with the Southern lines, the L. & S. W. Co. has only three expresses, their destination being Exeter. The best of the trains has a journey speed of 42⅓ and a running average of 45 miles. The London, Brighton and South Coast has fifteen expresses with an journey speed of 41⅓ and a mean running average of 42; besides which it has a capital service of fast trains which are almost express according to the foregoing definition. The South-eastern expends its energy on the Continental traffic, to which it devotes nine expresses, while it has only three others for the remainder of the system. The average journey speed is 41⅛ and running average 41¾. The London, Chatham and Dover completes the list of Southern lines, with nine trains having a journey speed of 42 and a running average of 43⅛. These four lines do not take kindly to expresses, and cling to the idea of making passengers pay extra for a rapid service. As compared with the Northern lines, their first and second class fares are 50 to 100 per cent. over the average, while they have no third class at all.

The Great Western occupies a middle position both geographically and in its characteristics. Its best trains are among the very first in England, but it is, in proportion to its size, more destitute of expresses than any line except the S. W. At present it numbers two Birkenhead trains, four Exeter trains, six between Bristol and Paddington, four between Birmingham and Paddington, one Irish boat express and two Weymouth trains, which are express only between Paddington and Swindon. The average journey speed is 40¾ and the running average is 44⅕. The longest and quickest run is from Swindon to Paddington, 77⅛ miles in one hour and twenty-seven minutes, or 53⅓ running average. The train which does this run is the fastest train in England, the fastest regular express in the world, and its average, which we annex, has therefore a particular interest.

ONE OF THE FASTEST EXPRESS TRAINS IN THE WORLD.

BROAD GAUGE "ZULU."				NARROW GAUGE.			
Miles.		Time.	Speed.	Miles.		Time.	Speed betw'n.
	Paddington dep., .	3.0			Paddington, . .	4.45	
			$53\frac{1}{5}$				$48\frac{4}{5}$
77	Swindon, ...	4.27		$63\frac{1}{2}$	Oxford, ...	6.3	
		4.37				6.7	
			47	$129\frac{1}{4}$	Birm., ...	7.27	$49\frac{1}{3}$
$106\frac{3}{4}$	Bath, ...	5.15				7.30	
		5.20		$41\frac{1}{2}$	Wampton, . . .	7.49	$38\frac{3}{4}$
			44			7.52	
$118\frac{1}{2}$	Bristol, ...	5.36		$171\frac{1}{4}$	Shrewsbury, . .	8.32	$44\frac{3}{5}$
		5.41					
			$52\frac{3}{5}$			8.35	
$168\frac{1}{4}$	Taunton, ...	6 32					
		6.35					46
			$47\frac{1}{3}$	$43\frac{1}{2}$	Chester, ...	9.30	
194	Exeter, ...	7.14				9.33	
		7.18		$228\frac{1}{4}$	Birken'd, . . .	9 53	$44\frac{1}{4}$
$246\frac{1}{2}$	Plymouth, ...	9.0			Liverpool, . . .	10.10	
	Journey speed, . .	$45\frac{3}{4}$			Journey, ...	$44\frac{1}{2}$	
	Running av., . .	$50\frac{1}{3}$			Running av., . .	47	

The G. E. has four groups of expresses for Doncaster, Colchester and Ipswich, Norwich and Cambridge and Harwich, numbering 34 in all, with an average journey speed of 41 and a running average of $43\frac{1}{4}$.

Next come the great lines connecting London with Lancashire and Yorkshire, and here is seen the nearest approach to perfection of express services. Of the three lines, the Great Northern and Midland rank far above the North Western, not in number of expresses, but in speed. The lengths of the three systems are:

Great Northern, ... 635 miles.
Midland, ... 1260 "
North Western, ... 1773 "

The express miles per day are respectively 6,780, 8,860 and 10,400; and the running averages $46\frac{1}{2}$, 45 and $43\frac{7}{10}$.

The G. N. runs 48 principal and 19 auxiliary expresses, averaging for journey speed 43 and running average $40\frac{1}{2}$. The specimen expresses are: Four Manchester trains with a running average of $50\frac{2}{3}$; the 1.15 down to York with $49\frac{1}{4}$; the 9 A.M. up from Leeds with 49, and the Scotchman with $49\frac{1}{2}$.

The Midland has a list of 66 expresses, with a journey speed of 41⅗ and a running average of 45. Its longest run is from St. Pancras to Leicester, 99¼ miles in 2 hours, 7 minutes, and its quickest, Liverpool to Stockport, 57¾ miles in 45 minutes. The line is very hilly and the trains almost uniformly heavy.

The London and N. W. is very favorably situated, for its gradients are easy and its course generally direct, consequently, as it is content to do its journey in the same time, it appears slack from an express point of view, when compared with its rivals. It runs 54 principal and 26 auxiliary expresses, averaging 40⅔ journey speed and 43$\frac{7}{10}$ running average.

The Manchester, Sheffield and Lincolnshire Railway Co. run 32 expresses between Manchester and Liverpool, occupying 44½ minutes on the journey, with a running average of 48¼.

It is interesting to compare the limited mail of the North Western, by no means one of the best of English expresses, with the very best long distance train on the European Continent, that of the Paris, Lyons and Mediterranean, the English train being third class and the French first class only. The former runs to Aberdeen, 540½ miles, in 14 hours, 5 minutes, stopping 15 times and 114 minutes, and climbing over two ranges of hills of 915 feet and 1,015 feet respectively. The latter has a course of 536 miles in 14 hours, 52 minutes, with eight stops, occupying 82 minutes, over a comparatively level country, and therefore is far behind in its results, what, for example, the G. N. of England would do if it had the same opportunities. The fastest train on the European Continent runs from Bordeaux to Paris, 359 miles, in 9 hours, 16 minutes, at a journey speed of 39½ and a running average of 43¾.

American Passenger Express Trains.

Our fastest train, says the *Railroad Gazette* of November 17th, 1882, is one between Jersey City and Philadelphia, making the 89 miles by the Pennsylvania Railroad in one hour and 52 minutes, which is 47⅔ miles per hour, and by the Bound Brook route substantially the same time is made.

The following table shows what American railroad companies have achieved in the matter of fast trains. The speed in all

cases is calculated by dividing the length of the route by the time between the two terminal stations, including stoppages on the way. In the same way, what is called journey speed in the foregoing summary of English expresses, is calculated.

ROUTE.	Length in miles.	Miles per hour.	Minutes per mile.
Jersey City—Philadelphia,	89	47⅔	1.26
Boston—Providence,	44	46⅓	1.29
Jersey City—Washington,	244	41⅚	1.43
New York—Albany,	142	40.6	1.47
New York—Buffalo,	440	40	1.50
New York—Boston (Shore Line).	232	39⅓	1.52
New York—Boston (via Springfield),	234	39	1.54
Jersey City—Pittsburg,	443	37.4	1.60
Windsor—Clifton (Great Western),	229	35.8	1.68
Detroit—Chicago,	284	35.1	1.71
Chicago—Pittsburg,	468	35.0	1.71
Buffalo—Chicago (Lake Shore),	525	34.4	1.74
Chicago—Jersey City (Pennsylvania Railroad),	911	35.6	1.69
New York—Chicago (N. Y. C. & L. S.),	965	36.3	1.65

The *Railroad Gazette*, commenting upon the relative speeds attained in England and America, says: "This certainly is not a very bad showing for a new country. Possibly one or two English trains equal the fastest American speed given above for 50 or 100 miles, but we think that none exceeds it, and so far as speed on long routes is concerned, we make the best showing, though, as there is more room here for long routes, that perhaps was to be expected. Only a few years ago we could not have made such a showing. On the Continent of Europe also there is greater speed and fast trains on more lines than was attempted five or six years ago. In England, however, there has been very little change for some years. The maximum, or a rate very near it, was attained there long ago."

During the past quarter of a century, American railways have made greater progress towards higher speeds than English railways. English railways were far ahead of American lines then. Still they lead us in speeds, but not nearly so much now as formerly. We have not yet quite overtaken them, but within the last few years we have considerably reduced the distance between them and us. We continue to gain on them, and as we approach their standard, the railroad engineers of America and England alike are putting forth their best efforts to advance in the direction of faster traveling.

Although the general tendency has been towards higher speeds, and although rapid strides have been made in some quarters, yet it is true that all the movements of all the railroads in America have not had acceleration for their result. It is noticeable that in some parts of the United States not only have speeds remained stationary, as in England, but the performances of today are considerably below the records of thirty years ago. For instance, in the beginning of 1881, a correspondent wrote to the *Utica Herald:* "In June, 1853, after the consolidation of the roads making up the New York Central, a time-table went into operation showing faster time than has ever been made since. The New York Express left Albany at 10.30 A.M. and arrived in Utica at 1.10 P.M., 2 hours and 40 minutes. The train making connection with this at Albany left the Thirty-first Street Station in New York at 6.25 A.M., thus achieving the distance from New York to Utica in 6 hours and 45 minutes. The fastest time today, with a bridge at Albany, is 7 hours and 10 minutes." It has only been within these past three years that we have had the present quick rate of transit—upwards of 47 miles an hour, including stoppages—between Philadelphia and New York. In the *Railroad Gazette* of November 11th, 1881, we find the beginning of this quick service recorded as follows: "Fast Passenger Locomotive for Pennsylvania Railroad. The first engine, or No. 10, has been employed in hauling trains Nos. 31 and 38 on the New York Division (between Philadelphia and New York), the schedule time of which trains is about 47 miles per hour, which includes two stops in 90 miles."

Here is a comment on the slowness of the progress made with regard to speed attained on the lines connecting New York with Chicago. On Nov. 2d, 1881, the *Railroad Gazette* says: "On Saturday announcement was made that a fast train would begin to run on Monday, making the time between New York and Chicago (926 miles) in 26 hours, which gives an average speed of 35 miles an hour. The fast train is a strictly limited one. It makes stops at only five places between the termini, and stops nowhere for meals. The speed of this train has been equaled or surpassed on several shorter routes for many years; indeed, about 1856, there was a faster train between New York and Albany, as there are

trains between those places now which run 36 miles an hour. What makes the new train remarkable is that it should make such speed for so great a distance; but even in that particular it is but a slight improvement on what has been done before. People have hardly forgotten yet the fast mail train that ran between New York and Chicago over the New York Central and the Lake Shore in 1875 and afterwards. The schedule time of this train was $27\frac{1}{4}$ hours, and it made it usually, and made many more stops than the new Pennsylvania train. This route, too, is 968 miles long, and the average speed per hour was $35\frac{1}{2}$ miles. In view of the success of its fast train between New York and Philadelphia, which for a year has run $88\frac{1}{2}$ miles in 110 minutes, it would seem possible for it to improve upon the time of 26 hours from New York to Chicago."

But, though advancement in particular instances has not been what we might have expected, yet, on the whole, the record of progress in the United States has been very good, and to-day efforts, as energetic as ever before, are being made in pursuit of the same object. In no other branch of science or industry do we endeavor more persistently still

> "To act that each to-morrow
> Finds us farther than to-day."

As a recent instance of the general and constant desire for higher speeds on our railroads, the newspapers within the past few days reported that on June 14th the House of Representatives agreed to increased appropriations for the Railway Mail Service, which will enable the Postmaster General to improve the service from Boston to New York and to the West, as well as the service from Philadelphia, and Baltimore, Washington, Richmond, Wilmington, N. C., Charleston, Savannah, Jacksonville and Pensacola to New Orleans. It will quicken the time between Philadelphia and New Orleans 12 hours.

Are Still Higher Speeds Wanted?

The answer of everybody and everything is, "Yes, certainly."

Mr. Percy Westmacott, in his Presidential Address, delivered at Liege, in Belgium, on the 23d of July, 1883, to the Institution of Mechanical Engineers, took occasion to say:

"In railway traveling it would seem as if for the present we had reached a maximum. It is surprising how soon the speed of the locomotive was brought up to something like its present limit. George Stephenson was laughed at in 1825 for maintaining that trains would be drawn by a locomotive at the rate of 12 miles an hour, but the 'Rocket' herself attained a speed of 29 miles an hour at the Rainhill competition in 1829, and long after ran 4 miles in 4½ minutes. In 1834 the average speed of trains on the Manchester and Liverpool Railway was 20 miles an hour; in 1838 it was 25 miles an hour, but by 1840 there were engines on the Great Western Railway capable of running 50 miles an hour with a train and 80 miles an hour without. In 1841 we find Stephenson himself ranged on the side of caution, and suggesting that 40 miles an hour should be the highest regular speed for trains. Now, it is a remarkable fact that the highest speed at which locomotives run in ordinary practice scarcely seems to have been raised during the last 25 years; on the other hand, the weight of the trains has been perhaps doubled. Although the average running time of express trains has been in many cases improved, this has been almost entirely due to their making fewer stoppages. At the same time, the speed attained occasionally is very great. Engines on some of our principal lines have repeatedly run 15 miles in 12 minutes, or at a speed of 75 miles an hour, and express trains run regularly at 53 miles an hour. It does not follow, however, that there is never to be any increase in the speed of trains, and it seems a point well worthy of consideration in what way the time of transit between important centres of trade can be shortened. What are the causes which have tended to prevent any improvement in this particular? In the first place, it may be said that the permanent way would suffer seriously by further increase in speed, but this could surely be overcome in time by improving the permanent way itself, which also remains very much in the same condition and of the same construction as it was 25 years ago. Again, it may be said that the running at a higher speed would require more powerful engines, and hence that trains now worked by a single engine would require two or would have to be split up into two trains at a great increase in running expenses. This, however,

assumes that it is not possible so to improve the engine that it shall be able to exert a considerably higher power without an inadmissible increase in weight. By utilizing a larger part of the total weight of the engine as adhesion weight, it would be easy to obtain the amount of adhesion required for the increased tractive force; and for this purpose Mr. Webb's compound locomotive engine, which enables the number of driving wheels to be increased without the use of coupling rods, appears to merit particular attention. In conclusion, it should be remembered that high speed, especially the speed of rotation, is almost necessary to give perfect accuracy and steadiness to motion, as in the case of an ordinary spinning top or a gyroscope, and again of the ingenious centrifugal machines now in use for separating cream, etc. The speeds which we find in nature are beyond all conception high, and her operations under these speeds are absolutely true and perfect. We cannot hope to vie with nature in speed and accuracy, but in this, as in many other great lessons taught by her, we see the direction in which we must travel in our efforts towards the perfection of work."

Recent Multiplication of Freight Traffic on American Railways.

The demand for powerful locomotives is seen hardly more clearly in the efforts being made all around towards the attainment of fast passenger transit, than in the enormous increase that has been taking place during the past few years in the freight traffic eastward. It was said at one time that three-quarters of all the freight from the West to tide-water went by two canals, chiefly the Erie, which left but two millions of tons annually to be moved by four trunk lines. But that state of things soon changed. In 1860 the New York Central and Hudson River Railroad, the New York, Lake Erie and Western Railroad, and the Pennsylvania Railroad about equaled each other in ton mileage, which amounted for each of the railroad systems to a little over three-fourths of that of the canals. In 1870 each of the roads named equaled the whole of the canals, and in 1880 doubled them in ton mileage. This seems to be explained by the fact that in 1880 the canals could carry no more or little more

than in 1870, while the weight of produce to be moved was enormously increased, and its removal devolved on the railways. As an example of increased traffic we may say that in 1870 the United States exported 20,219,368 bushels of grain, while in 1880 they exported no less than 258,119,883 bushels; and taking the whole of their food, oil and cotton exports, we find that between 1870 and 1880 they increased 464 per cent. To perform the greatly increased work which devolved upon them, the railways have had to multiply both the number of their tracks and the speed of their trains. In some cases the lines have not only been doubled, but quadrupled, two lines being kept for passenger and two for goods traffic. This development is instanced in the traffic returns of the Pittsburg, Fort Wayne and Chicago Railroad for 1881. The length of that railroad was 468.3 miles, of which but 74.3 miles were double track, and during the year the mileage run over it was 2,015,298 by passenger trains, 7,916,719 by freight trains, and 320,897 by other trains; making a total train mileage of above ten millions and a quarter; that is, equal to about 6 passenger and 24 freight trains and one other train over the whole length of the road, both ways, every day in the year.

The growth of traffic in recent years has not been and could not well have been effected by crowding on proportionately more rolling stock. It could only be done by employing more powerful engines, traveling at higher speeds, and getting more work out of the carriages. Considerable alterations have been made during the last few years in the system of working locomotives in the United States. At one time each engineer had his own engine, and when he rested, so did his engine; but at present the engines are worked on what is known as the "first in, first out" system, and by keeping more men than locomotives, there is more work got out of the latter. On the Pennsylvania Railroad in 1870 the average number of miles run per annum by goods engines was 19,214; in 1878 it was 20,000; in 1879 it rose to 24,355, and in 1881 it got up to 27,644; the average ton mileage in the last year being 5,100,000.

The late Mr. J. Edgar Thomson, President of the Pennsylvania Railroad Company, stated, in 1867, that the speed of a freight train should not exceed 6 miles an hour. The time-table speed

of American goods trains is now 15 to 20 miles an hour, or one-half to three-fourths of that of most English goods trains, which is higher than the speeds adopted for the haulage of goods in any other country. Coal trains on some lines in England are run at over 30 miles an hour.

Mr. W. B. Shinn, in a paper read before the American Society of Civil Engineers, speaks strongly on the necessity of getting as much work as possible out of each car, truck or wagon, and he argues with much force that the remedy for a block of goods on the road is not more cars, but more work got out of each car; while he maintains that the more rolling-stock any company possesses, the smaller will be the quantity of work got out of that stock. In proof of this he gives figures. Thus, while on Union Line, in the years 1879, 1880, 1881, 1882, the number of cars were respectively as 1, 1.16, 1.44, 1.49, the average of miles run per secular day in 1879 bore to that of 1880, 1881 and 1882, respectively, the proportion of 1.29, 1.48, 1.77 to one. The argument applies equally to locomotives.

Train Resistances.

The formula given in Clark's "Railway Machinery" for calculating resistances of trains is

$$R = 8 + \frac{v^2}{171}$$

in which R = resistance in lbs. per ton of 2240 lbs., 8 = constant resistance at all speeds, v = velocity in miles per hour, and 171 is a constant deduced from experiments with English trains.

On the ground that 8 pounds per ton is too high for the constant resistance of American cars, and that the constant 171 seems too little for the resistance of American rolling-stock at high speeds, the formula used in the "Catechism of the Locomotive" for calculating the table of resistance of railway trains is

$$R = 6 + \frac{v^2}{171}$$

in which R = resistance in lbs. per ton of 2,000 lbs. This gives a somewhat less resistance for the lower speeds, and greater for the higher ones than Clark's formula. With this formula the resistances for speeds up to 100 miles per hour have been calcu-

lated and are as follows:

SPEEDS.		RESISTANCES.	
5	miles per hour,	6.1	lbs per ton.
10	" "	6.6	" "
15	" "	7.3	" "
20	" "	8.3	" "
25	" "	9.6	" "
30	" "	11.2	" "
35	" "	13.1	" "
40	" "	15.3	" "
45	" "	17.8	" "
50	" "	20.6	" "
55	" "	23.7	" "
60	" "	27.0	" "
63	" "	30.7	" "
70	" "	34.6	" "
75	" "	38.9	" "
80	" "	43.4	" "
85	" "	48.2	" "
90	" "	53.4	" "
95	" "	58.8	" "
100	" "	64.5	" "

Thus, at 70 miles per hour, the resistance is 68 per cent. greater than it is at 50. A calculation made in an editorial in the *Railroad Gazette*, for September 15th, 1882, goes to prove that an engine with 5 foot wheels capable of pulling a train of 6 cars (weighing, with engine and tender, 200 tons) at 50 miles an hour, would be able to move only itself and its tender at a speed of 85 miles. "The diminution of tractive power on the one hand, and the increase of resistance on the other," says the writer of the article, "very soon limit the speed of a locomotive of any given size. We have very nearly reached," he proceeds to say, "the practical limit of speed of trains, unless there is some radical improvement made in the motive power employed. Fifty miles an hour, including stops, is the best time that can be expected

for regular trains, and any considerable speed over 60 is probably impossible."

Resistance of Grades.

Mr. O. Chanute, M. A. S. C. E., in Haswell's Engineer's and Mechanic's Pocket Book, divides train resistances into four principal elements; grades, curves, wheel friction and the atmosphere. Gradients, he says, generally oppose the largest elements of resistance to trains. Their influence is entirely independent of speed. The measure of this resistance is equal to the weight of the train multiplied by the rate of inclination or per cent. of the grade. Thus a gradient of 0.5 per 100 feet (26.4 feet per mile) offers a resistance of $\frac{5 \times 2{,}000}{10 \times 100} = 10$ lbs. per ton of 2,000 lbs., or 11.2 per ton of 2240.

Resistance of Curves.

The most recent European formula for the resistance of curves is that given by Baron v. Weber:

$$.06504 - R - 55 - W.$$

R representing radius of curves in metres. This formula assumes that the resistance due to the curve increases faster than the radius diminishes, but both reasoning and experiment indicate that the general resistance of curves increases very nearly in direct proportion to the degree of curvature, or inversely to the radius. Recent American experiments show that a safe allowance for curve resistance may be estimated at 0.125 of a pound per net ton for each foot in width of gauge. Thus for 3 ft. gauge resistance would be 0.375 lb. per degree of curve; for standard gauge (4 ft. $8\frac{1}{2}$), 0.589, say 0.60; and for 6 ft. gauge, 0.75 lbs. per degree. For standard gauge, when radius is given in feet, resistance due to this element is

$$\frac{0.60 \times 5{,}730 = C}{R}$$

in lbs. per ton of train.

Resistance by Friction.

Experimenters are not agreed whether the friction of the wheels increases simply with the weight which they carry, or

also in some ratio with the speed. Originally assumed as a constant at 8 lbs. per ton, improvements in the condition of the track (steel rails, etc.), and in the construction and lubrication of rolling-stock, have reduced it to 3.5 and 4 lbs. per ton for well-oiled trains. Under ordinary circumstances, in summer, it will be safe to estimate it at 5 lbs. per ton on first-class tracks, and 6 lbs. per ton on fair tracks. It may run up to 7 or 8 lbs. per ton on bad tracks (iron rails) in summer, and all these amounts should be increased from 25 to 50 per cent. in cold climates in winter, to allow for inferior lubrication.

Atmospheric Resistance.

Atmospheric resistance to movement of railway trains, complicated as it is by the wind which may be prevailing, has not been accurately ascertained by experiment. It is only a small proportion of the total resistance of a train at slow speed, but a very important element at high speeds. Experiments in gunnery indicate that at high speeds it is considerably greater than is usually supposed. In the article on "Gunnery" in the new *Encyclopædia Brittanica*, we find it stated that the resistance of the air to slow movements of say 10 feet per second, seems to vary with the first power of the velocity. Above this the ratio increases, and, as in the case of the wind, is usually reckoned to vary with the square of the velocity. Beyond this it increases still further, till at 1,200 feet per second resistance is found to vary as the cube of the velocity. The ratio of increase, after this point is passed, is supposed to diminish again. But thoroughly satisfactory data for its determination do not exist. Experiments with rifled projectiles in 1861 led Prof. Hélie to the conclusion that the resistance of the air at practical velocities was more nearly proportional to the cube of the velocity than to any other working expression. In 1865 and 1870, Prof. Bashworth, at Woolwich and Shoeburyness, found that velocities and forms being equal and similar, the resistance varies exactly as the square of the diameter of the projectile.

In practice it has been found, says Mr. Chanute, that an allowance of 1.5 to 2 lbs. per ton of the weight of a freight train covers atmospheric resistance, except in very high winds. The

following formulæ, he says, if applied with judgment and modified to fit the circumstances, will be found to give fairly accurate results in practice. They are for standard gauge, and in making them, the curve resistance has been assumed at 0.5 lbs. for one degree, the wheel friction at 5 lbs., the exposed end area of the first car at 90 square feet for passenger cars, and 68 feet for freight cars, and the increment for succeeding cars at 0.4 (40 per cent.) for passenger trains and 0.2 (20 per cent) for freight trains.

Resistance to passenger trains.

$$W(G + \frac{C°}{2} + 5) + (1 + \frac{N—1}{25}) 90\ P = R$$

Resistance to freight trains:

$$W(G + \frac{C°}{5} + 5) + (1 + \frac{N—1}{5}) 63\ P = R$$

W representing weight of train without engine, in tons; G resistance of gradient per ton; $C°$ curve in degrees; N number of cars in train; P pressure per square foot due to speed, to which an allowance must be made for wind if existing; R resistance of train, and 5 wheel friction, both in pounds.

On the subject of resistance of trains, a recent writer in *The Engineer* says: "It seems, rightly or wrongly, to be accepted by Locomotive Superintendents, that the resistance at 60 miles an hour is 40 lbs. per ton on a dead level; but there is reason to believe that this is an erroneous estimate. For a gross load of 300 tons we should have $\frac{300 + 40 + 88 + 60}{33000} = 1536$ H. P., instead of 1000; and our own experience leads us to believe that at 70 miles an hour the resistance does not exceed 40 lbs. per ton for the whole train in good weather and on a good road." And on this question the following testimony comes from a gentleman in Swindon, the seat of the G. W. Railway locomotive works in England: "My own experience goes to show that at speeds up to 60 miles an hour, the resistance is possibly not more than 28 lbs. per ton, but at higher speeds it rapidly augments. The Great Britain Broad Guage engine has done 53¼ miles in 47 minutes, with a train weighing, engine and tender included, about 100 tons. Experiments carried out by Babbage, with a dynamometer

van, showed that the gross resistance at 75 miles an hour—the highest speed attained—was 42 lbs. per ton on a level. The engine indicated nearly 1000 H. P."

Have we Reached Maximum Speed in our Locomotives?

This is the question which, more than any other, has recently engaged the attention of locomotive engineers. It has been widely and earnestly considered, and discussed, and disputed. The more it is considered the more invincible seem the difficulties which bar the way to improvement; and in England especially, where so little progress in regard to speed has been made during the last quarter of a century, there seems to be a conviction steadily growing that the limit has nearly been reached, and that much higher speeds are not possible of attainment on our present railways. But workers in the direction of greater powers and faster traveling are not yet satisfied to "rest and be thankful." Many of the great English railway companies are now building locomotives intended to attain very high speed with heavy trains; and those who have watched the process of development of the locomotive, know that there is a growing desire, manifested by the direction which this development is taking, for higher and higher speeds. It remains a fact that the average velocity of 60 miles an hour running time, that is, exclusive of stops, is not attained on any railway in the world.

In March last, a contributor signing "L.," endeavored to show, in the columns of *The Engineer*, not so much what could or might be done in this regard, as what appeared impossible. After examining the possibilities of improvement in speed, that gentleman does not quite see how any great improvement is to be made. One thing he is confident of, and that is, that it cannot be done without a wide departure from present methods of construction. The only positive suggestion he makes is the adoption of driving wheels as large as nine feet diameter. This, like every other suggestion in connection with a troublesome problem, finds people ready to subscribe to it without much examination; but the supporters of this one are so few that it may be considered almost singular and entirely barren. The advocate of it enters into an elaborate analysis of the work involved in traveling at

the average rate of 60 miles an hour, and after pointing out that a great deal of lost time cannot be overtaken, but that locomotives must approach average speed on long gradients, and must therefore be capable of attaining sometimes a speed of 75 miles an hour, he expresses the belief that an engine intended to run steadily and safely at 75 miles an hour, must have a single pair of drivers only, and that 9-feet wheels would be indispensable. He acknowledges that a wheel of this size entails outside cylinders as a matter of course, and that even with these, the centre of gravity of a narrow guage—4 ft. 8½ in. engine—must be raised considerably; but he disputes the prevailing notion that a high centre of gravity is a defect, and appeals for evidence to the fact that the L. & N. W. engine, Cornwall, ran with great success for many years with 9-feet driving wheels.

While recognizing fully the great difficulty placed by long gradients in the way of attaining continuous fast runs or even a high average speed, he is of opinion that, on the whole, curves will be found more serious impediments to high speeds than reasonable inclines will be; and one important consideration in favor of the utmost acceleration compatible with safety, is the noteworthy fact that the higher the speed the less will gradients affect the work to be done by the engine. A gradient of 1 in 264 will represent a resistance of 8.5 lbs. per ton nearly. This would be about the resistance of a train at 25 to 30 miles an hour. Such a gradient would therefore double the work to be done by the engine of a slow, heavy train, but will augment the resistance of our fast express by little more than one-fifth.

The Boiler Power Difficulty.

On October 13th, 1882, an article in the *Railroad Gazette*, after postulating "If a continuous speed of 60 miles an hour is to be maintained with the increasing weight of trains which the present traffic demands, we must certainly allow that a considerable increase of boiler power lies at the root of the whole question," goes on to say that "the steam which we have at our disposal with the boilers, might be used to much greater advantage than it now is with the single cylinder and the link gear. This," the article says, "is in fact accomplished by the Webb engine, now

running in England. The substantial success of the Webb engine clearly indicates that it affords the final solution of the matter." By the same writer it was then stated that the London Northwestern compound engine had effected a reduction in consumption of fuel of over 25 per cent. But all this, and much more, was written in a spirit more sanguine than scientific, before reliable tests had been made; and more recent accounts seem to indicate not only that these extravagant expectations have not been realized, but also that it is doubtful whether Mr. Webb's compound engine is, in respect of either economy or power, much of an improvement on its predecessors.

Now, in regard to the proposition laid down in the *Railroad Gazette*, that a considerable increase of boiler power lies at the root of the whole question, let us see what the specialist of the *Engineer* has to say on the point. He calculates that to draw a train weighing in all 175 tons (carriages, 100, and engine with tender, 75), on a level track at an average of 65 miles an hour (allowing 40 lbs. resistance to the ton), would require an exertion of 1213 indicated H. P. in the engine, and with the narrow guage, he says, it will be found impossible to use a boiler capable of developing much over 1200 H. P. The meaning of this is that if we wish to travel above 65 miles an hour on the level, we must keep the gross weight of our trains below 175 tons, or if we want to draw heavier trains, we must content ourselves with slower movement. One writer says, with certain limitations, our only hope lies in more boiler power, and the other believes that increased boiler power is hopeless. After considering the difficulties in the way of designing an effective boiler for the fast engine, which is to have the indispensable 9 feet driving wheel; after contemplating the enlargement of the fire-box on the Wootten system by spreading it behind the driving wheels, and the adoption of Crampton's type of engine as an alternative scheme, and finding in none of them any help to the solution of the problem, the specialist in the *Engineer* gives his discouraging conclusions as follows: "So great, indeed, are the difficulties which stand in the way and bar our progress, that we are forced reluctantly to the conclusion, that it is impossible to design a narrow gauge engine which shall develop 1200 indicated H. P. steadily for an hour,

and yet shall be anything like the ordinary type. If this be the case, then it is not easy to see how runs of 60 miles can be accomplished in 60 minutes."

Possible Ways Out of the Boiler Difficulty.

In an editorial on May 16th, the *Engineer* labors, as below, to prove that at all events it is not impossible to construct a boiler capable of supplying the steam necessary for driving a higher speed locomotive:

"There are three different ways in which sufficient boiler power —say 1500 horses—can be obtained on a narrow guage (4 ft. $8\frac{1}{2}$ in.) road. The first consists in so constructing the engine that the fire-box shall be nearly the whole width of the machine. The second consists in altering the construction of the grate; the third, in adopting mineral oil as a fuel, either in conjunction with coal or by itself. The fire-box scheme seems perfectly feasible, for Mr. Wootten has run his engines successfully at 75 miles an hour. Their driving wheels are only 5 ft. 8 in. diam. and their grates are 9 ft. long by 8 ft. wide. The true difficulty about the Wootten engine appears to be the excessive speed at which the reciprocating parts must move. A 5 ft. 8 in. wheel running at 75 miles an hour makes nearly 366 revolutions per minute. With a piston stroke of 2 ft. this means 1464 ft. of piston speed per minute. There is no objection to this high velocity, but there is a great deal to the fact that the piston with all its appendages, as the crosshead, connecting rod, etc., should have to be stopped and started 732 times in a minute. But Mr. Wootten manages to get his engine over the road at 75 miles an hour without accidents.

"Is it essential that the grate in a locomotive should be a plane? Let us suppose that it is not essential, and that the ordinary fire-box of a locomotive is fitted with a species of basket grate to be kept constantly filled with coal. This basket might be in round numbers 2.5 ft. by 5 ft. Thus, the area of the bottom of the basket would be 12.5 sq. ft. The two sides, if each 1 ft. deep and 5 ft. long, would give 10 feet. and the two ends would give 5 ft. Thus, the total grate area available for admission of air would be $12.5 + 10 + 5 = 27.5$ sq. ft. Here, then, we would have at once, and almost without any change whatever in the engine, an in-

crease of over 50 per cent. We believe there would be no great difficulty in making such a grate durable. The sides might, indeed, be made of water tubes, in which there would be nothing new, such water tube bars being freely used in the United States, although for a different purpose; but in any case the experimental use of a cage grate presents no difficulty whatever and would involve an outlay of less than 10 pounds, as it might be fitted to any engine without involving the smallest structural change in the existing fire-box."

Speaking of petroleum as fuel, the same writer sees nothing but its cost to stand in the way of its adoption.

ECONOMY OF FUEL.

English vs. American Locomotives.

The relative degrees of economy in the consumption of coal attained by British and American locomotives has long been a subject of dispute, and has given rise to a good deal of high feeling and tall talk on both sides. But the different conditions under which the two classes of engines are worked render it impossible to make an accurate comparison of their performances. Until we get an American and an English locomotive placed on the same track, under a single control, and coupled to the same task, no reliable test can be made. But, up to the present, evidence and opinion have been in favor of the English engine in respect of economy of fuel. Mr. Angus Sinclair, writing to the *Railroad Gazette*, of October 6th, 1882, says: "There is good reason to believe that the average evaporative duty of American locomotives does not reach 5 lbs. of water to the pound of coal consumed, while there are locomotives running in Europe which approach an evaporative duty of 10 lbs. On the London & N. W. Railway, in England," he says, "express engines, making an average speed of 45 miles per hour and pulling a train equal to 6 American coaches, burn from 25 to 30 lbs. of coal per mile, while we have very few engines that will perform the same work without burning 40 lbs. per mile." Mr. Sinclair traces the cause of the economical results reached in British practice to the superior methods of fire management developed by strict smoke-forbid-

ding ordinances, to the wide nozzles rendered practicable with the clear smoke stack, and to the emulation in coal-saving engendered by the system of granting premiums to the firemen according to results. On the other hand, the wastefulness of American practice he assigns to the conserving of the stack obstructions which had been necessary for wood burning, and which were mostly retained when the wood, as fuel, was superseded by coal, and to the inherited carelessness of the American firemen, which had its origin in the cheapness of coal in days gone by. But he contends, also, that American engine-makers continue to violate the principles upon which fuel saving is based; and that many locomotive builders exhibit extreme carelessness about supplying the means of regulating the draft. But although finding fault with the American locomotive on the score of economy, he does not disparage it as a whole. On the contrary, he says: "I have met a great many locomotive engineers who have run engines on both sides of the Atlantic, and I never yet conversed with one of them who did not prefer the American engine. For convenience in handling, for freedom from the innumerable small defects that entail torture on the road with British engines, and for general durability, there is no engine running on wheels that can compare with the American locomotive." Mr. Edgar Worthington says, that he has known an English engine, with one pair of driving-wheels, to carry the "Irish mail," composed of 5 or 6 six-wheeled carriages, for a month, on 23 lbs. of coal per mile. Comparing Mr. Webb's statement, that his coupled engine (17 x 24) burns about 30 lbs. of coal per mile with a load varying between 8 and 17 six-wheel English coaches, and the locomotive return list published in America in June, 1882, showing that the coal burned per mile on heavy trains averaging 5.25 passenger cars, was 62 lbs., he says: "Roughly speaking, this means as follows: That an American engine with 5.25 passenger cars burned twice as much coal as an English engine did hauling the same weight, supposing an English six-wheel carriage to weigh about half as much as an American car." Mr. Worthington enumerates the following obstacles which operate against the American locomotive in the competition of economy: "The loss by friction of curves in America is greater,

the grades are more frequent; the entire heating surface of an English engine is of copper or brass, which has a conductivity for heat of say 100, while the entire heating surface of an American engine, though the fire-boxes are slightly thinner, is of iron and steel, whose conductivity in comparison is only 15.8."

The late Mr. Howard Fry, writing to the *Railroad Gazette* of November 10th, 1882, gave the following returns at random from reports of average consumption of fuel per mile, on various roads, for passenger trains:

Lake Shore & Michigan Southern Railroad, . .	55 lbs.
New York, Ontario & Western Railroad, . . .	65 "
New York, Pennsylvania & Ohio Railroad, . .	67 "
Louisville & Nashville Railroad, ...	38 "
Pennsylvania Railroad—New York Division, . .	58 "
Philadelphia Division, . .	60 "
Middle Division, . . .	43 "
Pittsburgh Division, . .	52 "
New York Central & Hudson River Railroad, . .	34 "

Taking the Pennsylvania Railroad as being a fair representative of average American practice, he thought it was safe to say that with a moderately heavy train on a road with medium grades, an American locomotive burns 50 lbs. per mile. What an English locomotive would do with the same train, could only be ascertained by bringing one over and trying. In his own opinion, based on a long experience in both countries, an English locomotive would take say 5 cars over the New York Division in 2 hours for 30 lbs. a mile. Mr. Fry agreed with those who believe that in locomotive designing, Americans have paid but little attention to economy of fuel and proper strength of details.

Slow and Fast Traveling.

As there is no certainty about the rate at which resistances increase with increased velocities, so there is in existence no data from which we can evolve a formula to express accurately the relative proportions of fuel consumed per ton mile in running trains at varied speeds. As has been seen, the resistance increases in a much greater ratio than the pace; and an impression seems

to prevail in some quarters, that, at a given amount of coal, owing to the loss in the wire drawing of the steam through the ports, rather less power is developed at high than at low speeds, and consequently that the consumption of fuel increases faster than the resistance. But either this is not the case, or the recognized formulæ for calculating resistances are very far wrong, for it has happened in experimenting, that where, according to Clark's formula, the resistance would appear to have been more than doubled, the consumption of fuel has been raised by little more than one-half. But the observations of various practice and the results of different experiments, do not all agree. The differences are so great as to leave us still in the dark with regard to the matter. Indeed, in the "Transactions of the American Society of C. E.," for 1876, page 341, in an essay on "Resistances of Railway Trains," we find reference made to some tests conducted in 1876 on the Lake Shore & Michigan Southern Railway, in which it was found that the long and heavy trains of 650 to 700 tons on that line actually required less fuel with the same engine, to run at 18 to 20, than to run at 10 to 12 miles an hour.

Mr. Hodgson recently sent to the *Engineer* a diagram said to be prepared from the results of engines running regular trains on some of the main English lines, showing the rapid increase in the consumption of coal when a locomotive attains a very high speed. That diagram would indicate that at average speeds of 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 and 65 miles per hour, the consumption of coal was: .085, .09, .10, .115, .13, .15, .17, .20, .23, .27, .31 and .35 lbs. per mile per ton. But these figures differ considerably from those obtained by experiments tried a short time ago on the line between Bound Brook and Philadelphia. A regular five-car express train ran under usual conditions from Philadelphia to Bound Brook and back, a distance of 119 miles, making the usual stops and at schedule time, running average 55 miles an hour, and was found to consume 6725 lbs. of coal on the trip, which agrees pretty well with the returns of average practice on that road. The same train, running the same distance and making the same stops in 9 hours and 23 minutes, or at an average speed of a little over $12\frac{1}{2}$ miles an hour, burned 4420 lbs. of coal. The consumption at high speed was therefore an in-

crease of 52.1 per cent. over that at low speed. If we calculate the resistance according to Mr. Clark's formula, it will appear that 52.1 per cent. increase of coal, in this instance, overcame about 150 per cent. increased resistance. The English diagram would show the relative consumption of coal per ton mile at 12½ and 47 miles per hour to be as 0.087 : 0.215 lbs., while the Bound Brook tests show the figures to be about 0.1855 : 0.2826 lbs. Were both Mr. Hodgson's diagram and the figures of the Bound Brook tests reliable, a comparison would lead to the conclusion that high speeds are not nearly so relatively expensive in America as they are in England.

(To be continued.)

XXIV.

THE NAVIGATION OF THE AIR.

By Russell Thayer, Member of the Club.

Read December 20th, 1884.

From the earliest times man has sought the solution of the problem of the navigation of the air, and has endeavored to devise means by which he could be enabled to pass at will through the light fluid known as the atmosphere which surrounds the earth like an immense ocean, fifty miles in depth.

It is hardly necessary, in a paper of this description, to recall the many attempts that have been made by individuals totally deficient in a knowledge of the fundamental laws of physics to imitate the bird in his flight, by means of wings and other devices of a similar character.

It may be briefly remarked that these experiments have been signal failures, owing to satisfactory scientific reasons.

It is only within recent years that the conditions of the problem of aërial navigation have been studied by engineers, competent to deal with a matter of this description, and their investigations have proved that the navigation of the air is a question, the solution of which is dependent upon the accomplishment of

certain results quite within the range of applied mechanics of the present day.

Almost exactly one hundred years ago the discovery of the balloon solved one of the most difficult and important points in the problem, viz., the great obstacle to aërial operations caused by the action of the force of gravity upon all matter.

By means of the device of the balloon, we are now enabled to overcome the force of gravity and to float in the atmosphere. After this discovery the solution of the problem practically resolved itself into the discovery of means for applying force for the purpose of directing a balloon properly designed in shape, on a regular course through the air in any given direction.

Numerous attempts have been made to accomplish this result, and many devices, some of them the most absurd in their character, have been suggested and tried.

The extreme thinness and elasticity of the medium in which the body floats has baffled the ingenuity of the engineer and inventor in the application of a force for the propulsion of the aërial ship.

All methods of propulsion heretofore known have been tried and been found wanting, the idea in every instance has been to apply a surface of some resisting matter endowed with force against the air, the object in view being to obtain thereby a reactive force that would propel the air ship through the atmosphere. Ignorant persons have suggested wheels, oars and similar contrivances, while accomplished engineers, as de Lome and Giffard, have tried to adapt the propeller to the solution of the problem. All attempts heretofore made have practically been failures, although to Mr. Henri Giffard, the celebrated French engineer, the credit of first attempting to apply steam for the propulsion of a dirigible balloon can be given.

Another most important point in the final solution of the problem must be here referred to, viz., that it is only within the last few years that it has become possible to construct machinery of great power and extreme lightness combined with strength.

Mr. Wm. Pole, F. R. S., M. Inst. C. E., in the year 1882, read a paper before the Institution of Civil Engineers, of Great Britain, and discussed in a practical manner the problem of aërial navigation. The conclusions reached by him were as follows, viz.:

1. The problem of aërial navigation by balloon is one as perfectly amenable to mechanical investigation as that of aquatic navigation by floating vessels; and its successful solution involves nothing unreasonable or inconsistent with the teachings of mechanical science.

2. It has been fully established by experiment that it is possible to design and construct a balloon which shall possess the conditions necessary for aërial navigation, viz., which shall have a form of small resistance, shall be stable and easy to manage, and if driven through the air shall be capable of steering by a proper obedience to the rudder.

3. If by a power carried with the balloon, surfaces of sufficient area can be made to act against the surrounding air, the reaction will propel the balloon through the air in an opposite direction.

4. The modern invention of the screw propeller furnishes a means of applying power in this way to effect the propulsion, and the suitability and efficiency of such means have been shown by actual trial. (?)

5. Sufficient data exists to enable an approximate estimate to be made of the power necessary to propel such a balloon with any given velocity through the air.

6. The recent reduction in the weight of steam motors has rendered it possible to carry with the balloon an amount of power sufficient to produce moderately high speed, say 20 or 30 miles an hour through the air, and by taking advantage of other recent improvements it would also be possible to carry a moderate supply of fuel and water for the working.

7. The practical difficulties in the way are only such as naturally arise in the extension of former successful trials, and such as may reasonably be expected to give way before skill and experience.

Mr. Pole's entire investigation of the subject and the conclusions deduced, are based on the screw propeller as furnishing a practical means for the propulsion of an aërial ship.

A glance, however, at the tabular results reached by him, shows that as a means of applying the force generated by the steam the propeller is a most unsuitable and impracticable machine. Fancy a propeller 60 ft. in diameter (the size required

for a large aërial ship) and conveying a thrust of 3,000 lbs., the difficulties of constructing such an arrangement that would be of sufficient lightness and strength, and at the same time manageable, are insurmountable, and preclude its use for the purpose in question.

The propeller is a most suitable contrivance for the propulsion of ships in a heavy, incompressible fluid like water, especially where weight is no consideration, but is totally unsuited for the propulsion of bodies in an extremely attenuated and elastic medium as the air. The propeller is practically out of the question, and we must seek other means to generate motion in this case.

I may here remark that the conditions which obtain in regard to a body floating in the air are similar to those which exist in the case of a ship floating in the water. In both instances the structure is supported in the medium in which it floats against the action of the force of gravity by the weight of the fluid displaced, this weight acting vertically upwards in opposition to the force of gravity acting vertically downwards through the centre of gravity; the force acting vertically upwards and sustaining the body in the fluid is called the "buoyant effort," and its intensity is equal to the weight of the fluid displaced, its line of direction passes through the centre of gravity of the displaced fluid, and this point is called the centre of buoyancy. The following conclusions result from a thorough investigation of this branch of the subject, viz.:

1. The pressures upon the surface of a body immersed in a fluid have a single resultant called the buoyant effort of the fluid, and this resultant is directed vertically upwards.

2. The buoyant effort is equal in intensity to the weight of the fluid displaced.

3. The line of direction of the buoyant effort passes through the centre of gravity of the displaced fluid.

4. The horizontal pressures destroy one another.

In regard to the equilibrium of the floating body, I may state that it will be stable as long as the centre of gravity of the body is below that of the displaced fluid. In the dirigible balloon that I have designed this condition will be always fulfilled, and consequently the structure cannot capsize.

Practical experiments and mathematical deductions prove that the best shape for the buoyant portion of the structure under discussion is that of a circular spindle, in which

$$l = 3\tfrac{2}{3}\ d$$

l representing the longer or horizontal axis, and d the diameter amidships. This shape will give the least resistance to motion through the air, will comply with the conditions of stable equilibrum, and will give good steering qualities.

The ascending force of the gas, hydrogen being used, will be represented by the expression

$$A\ d^2\ l$$

In which d and l represent quantities as above, and A being a coefficient depending upon the shape of the vessel and on the specific gravity of the gas compared with that of the surrounding air. Supposing pure hydrogen gas to be used, the levity of 1 cub. ft. = 0.0751 lb., and with the shape above given the ascending force determined by actual experiments may be represented by the expression

$$.03\ d^2\ l.$$

The resistance of the ship to motion through the air has been accurately determined by three methods, viz.:

By the midship area calculations.
" " skin friction "
" " cubic displacement calculation.

And based upon the conditions that $l = 3\frac{2}{3}\ d$ the following resistances have been obtained, viz.:

By the midship area $= 0.000172\ d^2\ v^2$.
" " skin friction $= 0.000173\ d^2\ v^2$.
" " cubic displacement $= 0.000211\ d^2\ v^2$.

In which d represents as above and v = velocity in ft. per second of time. Taking a mean of the two last expressions (the largest) the formula giving the resistance to motion forward through the atmospere becomes

$$X = 0.000193\ d^2\ v^2.*$$

---

* Pole.

The Theory of Action of the Aërial Motor.

To return now to the subject of the propelling force, I will observe that the idea of beating the air (a medium of extreme rarity) with a propeller in order to generate a reactive force forward is impracticable, not only on account of the practical difficulties in the way, as before suggested, but also and principally by reason of the unsubstantial character of the medium upon which the force is made to act, and the great waste of power resulting from any such method. After careful investigation of the subject, I was forced to adopt the conclusion that the propelling force must reside in the motor itself, and must be applied within itself in such a manner as to promote motion forward.

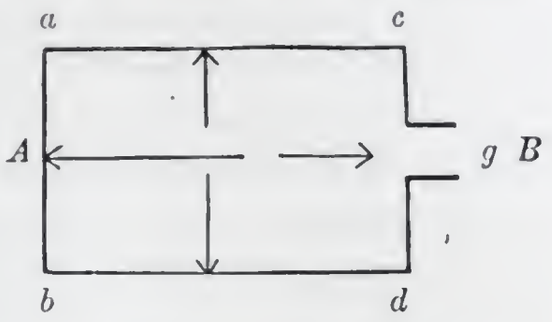
This proposition may seem at first to be impossible, but the action of the motor is entirely independent of extraneous conditions, and will produce high rates of motion without applying force against any extraneous resisting medium.

In all ordinary applications of force to produce motion, we see the force generated applied against some resisting substance. The steamboat is propelled by the reaction resulting from the action of the blades of the paddles, or screw, upon the dense medium of the water. The locomotive engine moves forward by reason of the peripheries of the drivers rolling along the rail, but the tires must grip the rail before motion results. Numerous instances of the application of force based upon the principles here involved may be enumerated.

In the case of navigating the air, however, there is nothing upon which, or against which the force generated can be applied; we are suspended in space, between the heaven and earth, and if we except the invisible, and extremely rare medium of the air there is nothing upon which a propelling force can act, extraneous to the machine itself. Under these circumstances we can only utilize the air as a medium, the weight of which causes a buoyant effort by which we can counteract the force of gravity and float.

In order to move in the air, I develop forces in unstable equilibrium, acting upon the motor itself and producing a resultant force which will cause the dirigible balloon to move in the direction in which said resultant is made to act.

The principles which I have adopted to produce this condition of continuous unstable equilibrum of forces, may best be understood from the following simple demonstration:



Case I.—Take a hollow cylinder, *a b c d*, with an outlet at $g = 1$ sq. in. in area. Now suppose this cylinder is kept constantly filled with a gas, air or vapor, under a pressure of say 100 lbs. to each square inch; suppose the area of each cylinder head $= 10$ sq. in. Under these circumstances the total pressure on the head *a b* will $= 10 \times 100 = 1{,}000$ lbs., but on the head *c d* there will only be 9 sq. in. upon which the force within the cylinder can act, consequently the pressure on this end of the cylinder $= 9 \times 100 = 900$ lbs.; all the other forces within the cylinder are in a condition of equilibrum, for the reason that they are all acting respectively in directly opposite directions and are equal; therefore the resultant of forces $= 1{,}000$ lbs.—900 lbs. $=$ 100 lbs. acts in the direction *B A*, and this will produce motion in that direction due to said resultant.

We have here generated a powerful force and applied it in such a way as to produce motion with the simplest possible mechanism, and entirely independent of extraneous conditions, and motion can be produced by this principle in a perfect vacuum remote from the reach and influence of all terrestrial objects; indeed it is evident that in a vacuum the motion of a body impelled by the action of a force resident within the machine itself by the principle above described, would be at a far higher rate of speed than would be the case in the air, for the reason that the medium in which the body is traveling, viz., the air, offers considerable resistance to motion due to friction.

The motor which I have devised enables me to accumulate, produce and apply a powerful motor force. It consists essentially of a high speed air compressor, coupled directly to a specially

designed gas engine and a reservoir into which compressed air is forced, or vapor is allowed to flow until the required pressure per square inch is obtained. The rear end of this reservoir is so arranged that, at given intervals of time, the confined energy is suddenly released, thus producing a powerful motive thrust forward *due to the fact of the unstable condition of equilibrium of forces at the instant of discharge.* The amount of power thus rendered available is dependent upon the size of the cylinder end and its discharge. It is also of course a function of the time of charging, and the number of strokes of the engine made therein By the use of the gas engine we have no coal or water, which are weighty sources of energy and inapplicable to the purposes in question. We thus use a fuel the weight of which is inappreciable. In the motor here described for aërial navigation, the impact of the escaping air, gas or steam, under high pressure against the particles of the surrounding air in which the body is floating, tends to increase the resultant action forward, but the principal portion of the motion forward is caused by the continuous condition of unstable equilibrum of forces producing a resultant action, as above described, in a given direction; the reaction resulting from the impact of the escaping gas upon the particles of the surrounding medium, is small in comparison with the resultant of the forces in unstable equilibrum, but slight as it is, it acts in the proper direction. I regard the aperture at the rear of the motor mainly as a means for the escape of the wasted energy, its size is so proportioned as to produce the maximum condition of unstable equilibrum of forces.

I may here remark that I have also adapted the motor to the propulsion of vessels on the water and vehicles on the land. I believe it to be capable of propelling structures either in the air, in the water, or on the land at considerable speed, and it possesses some advantage over methods heretofore employed for these purposes. In the case of navigating the air, however, it is the only principle that can be used advantageously.

I will now proceed to a description of the dirigible balloon. It consists essentially of two portions; the buoyant part, which corresponds to the hull of a water ship, is made of superposed tissues of strong silk and rubber, and the shape is that of a circular

spindle, in which the long horizontal axis = $3\frac{3}{5}$ times the length of the diameter amidships, this structure is filled with hydrogen gas.

The deck of the ship, upon which the machinery is placed and where passengers can be accommodated, is below the buoyant part of the structure and is firmly supported therefrom and braced thereto. Opposite the centre of the ship there is a lower deck, completely enclosed and separated from the rest of the structure in which the source of power is located. From the motor a pipe leads all or part of the wasted energy utilized in the production of motion to the stern of the ship, and is there terminated by a nozzle fitted on a ball and socket joint, this arrangement permits the nozzle to be moved in any direction at pleasure, and by a movement of the nozzle from the wheel, the ship may be steered in any direction that may be desired, thus avoiding the necessity for any rudder. While the machinery is in motion and the force is being generated, the dirigible balloon is under perfect control and can be directed in any course that may be required. It is not necessary that the entire amount of wasted energy should be discharged at the stern of the ship and used for steering, and so it is preferable not to do this, but to discharge the energy near the motor, and thus avoid the friction in the tube; a portion sufficient only to give good steering power should be taken to the nozzle at the stern. In the interior of the buoyant portion of the structure is placed a large silk sack connected with an air compressor on the deck, and a pipe leads from the exterior envelope to the tube leading to the nozzle at the stern, both of these pipes are provided with cocks which can be opened or shut at pleasure. There are four cylinders filled with compressed hydrogen on the deck of the ship, which are connected with the interior of the exterior envelope.

These appliances enable the dirigible balloon to travel at any elevation above the earth, and to ascend or descend in the atmosphere without the use of ballast. By simply withdrawing hydrogen from the interior of the exterior envelope and forcing air into the interior of the interior sack, the buoyancy of the structure is diminished, while its exterior form is not changed and the ship will descend, the reverse of this operation will restore the original

buoyancy and cause the ship to ascend. The importance of this matter will be appreciated when it is remembered that it is not proposed to travel habitually at high altitudes, but at elevations of a few hundred feet only, sufficient to clear terrestrial objects.

The following examples show the carrying capacities of dirigible balloons of various sizes, with the speed per hour and total resistances met with at the respective rates of motion; these elements are calculated from the formulas heretofore given in this paper.

In all cases d = diameter amidships, $l = 3\frac{2}{3}\, d$ = length.

$d = 30'$
$l = 110'$

Total ascending force 2,970 lbs.
Resistance 10 miles per hour, 38.04 + lbs.
" 20 " " 149.11 + "

$d = 40'$
$l = 147'$

Total ascending force 7,040 lbs.
Resistance 10 miles per hour, 67.62 + lbs.
" 20 " " 265.10 + "

$d = 50'$
$l = 183'$

Total ascending force = 13,725 lbs.
Resistance 10 miles per miles = 105.66 + lbs.
" 20 " " = 414.22 + "

$d = 75'$
$l = 275'$

Total ascending force = 46,400 lbs.
Resistance 20 miles per hour = 931.92 + lbs.
" 40 " " = 3727.69 + "

$d = 100'$
$l = 367'$

Total ascending force = 110,000 lbs = 55 tons.
Resistance 10 miles per hour = 422.67 + lbs.
" 20 " " = 1656.90 + "
" 40 " " = 6627.62 + "

Note these resistances at the speeds specified, and observe how very small they are in comparison to the size of the ship and its carrying capacity. It is only necessary for the motor to develop a force equal to the resistance in any instance to produce the corresponding rate of motion through the atmosphere.

The following table shows the speed in miles per hour that could be commanded on any proposed course by a dirigible balloon having an independent motion through the air of 30 miles per hour, wind supposed due north, blowing with velocities varying from 0 to 50 miles per hour (Pole).

Velocity of Wind.	N.	N. N. E. or N. N. W.	N. E. or N. W.	E. N. E. or W. N. W.	E. or W.	E. S. E. or W. S. W.	S. E. or S. W.	S. S. E. or S. S. W.	S.
Calm.	30	30	30	30	30	30	30	30	30
5	25	25	26	27	29	31	34	35	35
10	20	20	22	25	28	33	37	39	40
15	15	15	17	20	25	32	39	44	45
20	10	10	13	16	22	31	41	48	50
25	5	5	7	9	17	29	43	51	55
30						22	43	56	60
35							42	59	65
40							38	63	70
45								67	75
50								70	80

In conclusion, I would state that there are many uses to which the dirigible balloon may be applied. Compared with water ships, steamers and boats, it will be much more rapid in its movements and much less costly in construction. It will require no harbors, and in many respects will be far less dangerous; and for all purposes of exploration and for military observation, communication with and relief of besieged towns and general war purposes, it may prove in the future to be invaluable.

By its means impassable barriers of land, water and ice can be readily passed over, and when the poles of the earth are visited by man it will probably be by this method of transportation.

XXV.

MEASURING CHIMNEY DRAFT.

By H. W. Spangler, Member of the Club.

Read December 20th, 1884.

The amount of draft in a chimney is one of the many indications which assist us in forming an opinion as to whether or not a boiler is working satisfactorily and economically.

I propose in this paper to describe a few of the ways which have been devised for measuring this.

The connection with the chimney is usually made in the following way: A piece of gas piping extends into the chimney to about its centre, and should have a quarter turn at its end. The other end extends through the wall sufficiently to attach a piece of rubber tubing to it. The pipe is put in such a way that no air can enter the chimney around it.

The ordinary method of measuring the draft is shown in Figure 1. A glass tube, bent into the shape of a **U**, is partly filled with water, which should have a drop of aniline added to it in order that it might be more easily read. The top of one branch of the **U** should be open to the air, while the other should be attached to the chimney by means of the rubber tube before spoken of.

The joints of the tubing with the **U** tube and the gas pipe extending into the chimney should be perfectly tight; and, ordinarily, if sufficient of the rubber tubing is used at the joints, no air can enter.

The difference of pressure in the chimney and outside causes the liquid in one leg of the **U** tube to rise and in the other to fall, and the difference in level is a measure of the amount of draft or of the vacuum in the chimney.

In measuring the draft, the rule or scale should be held vertically.

When the amount of the draft is considerable, this method is convenient and as nearly exact as the scale can be read.

When the amount of the draft is small, considerable trouble is found in making satisfactory readings, because of the curved top

FIG. 1.

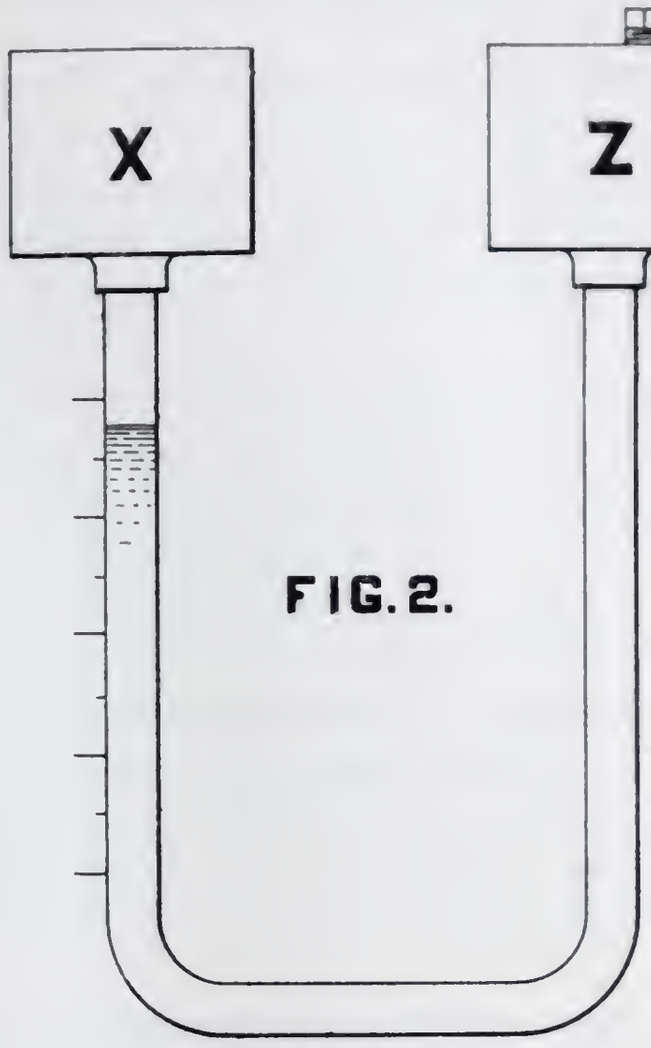


FIG. 2.

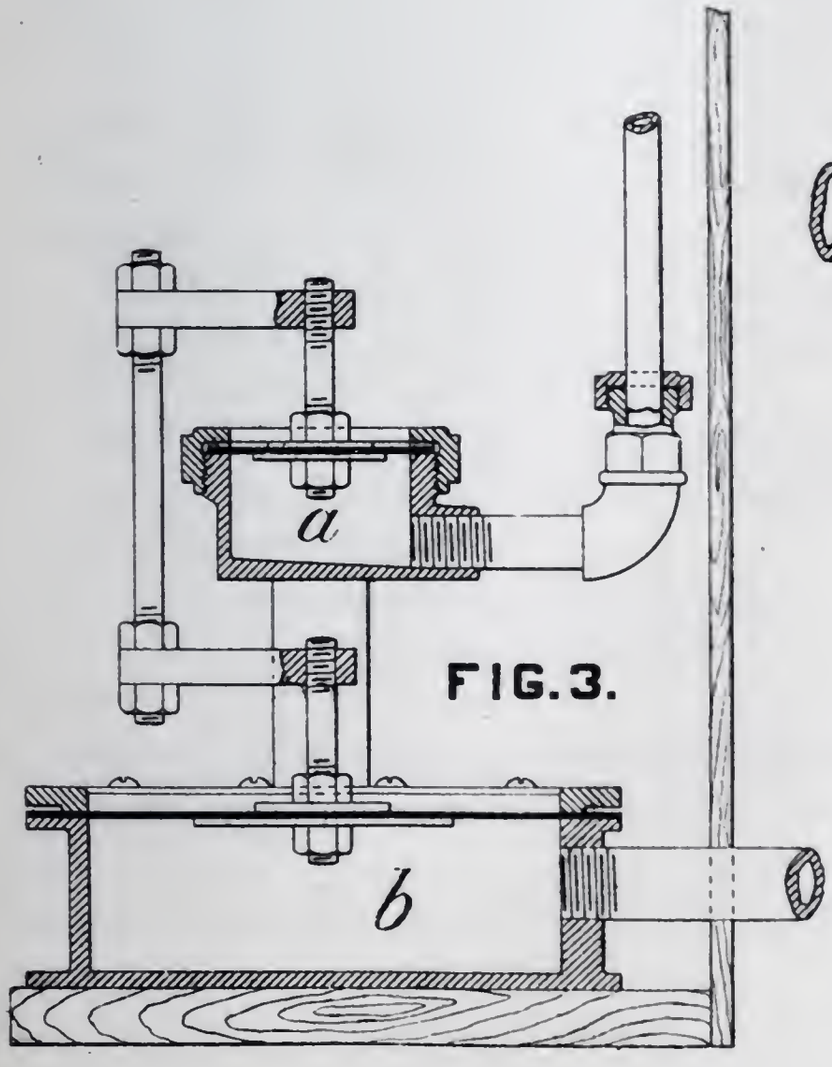


FIG. 3.

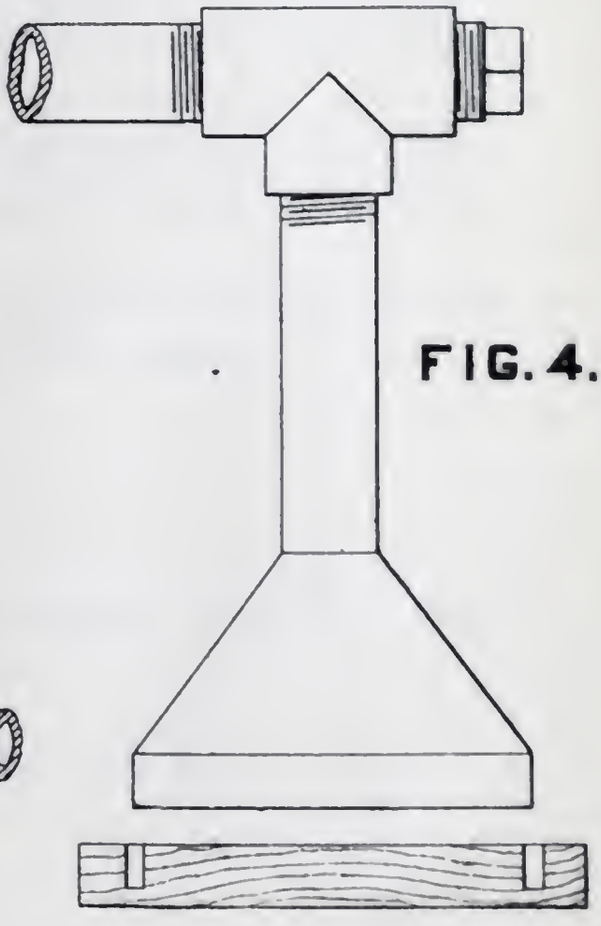
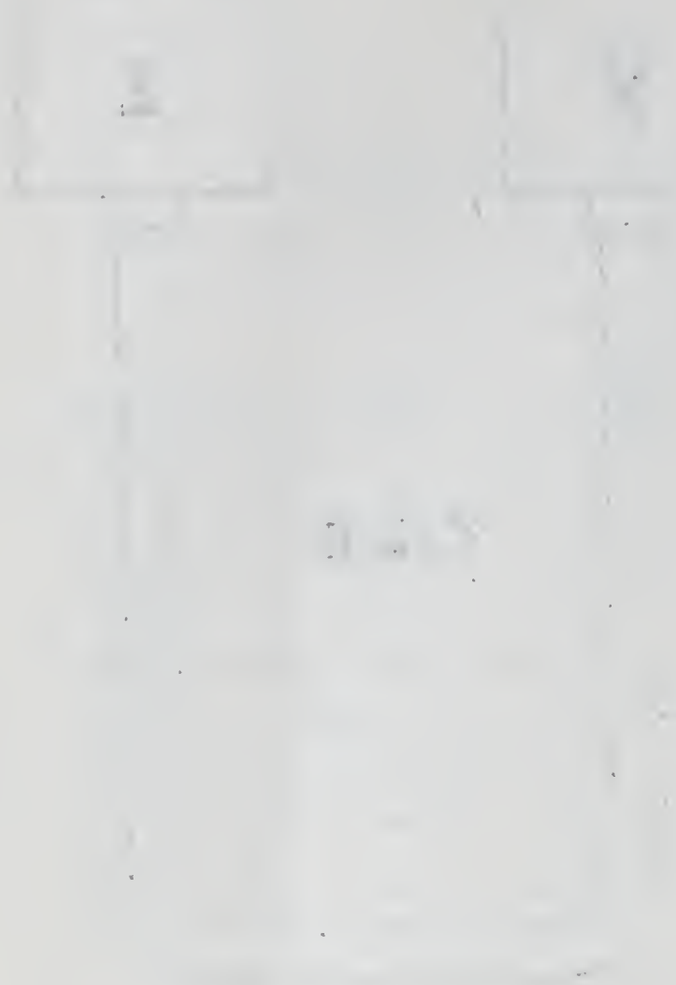


FIG. 4.



of the liquid in each leg, and the difficulty of holding the scale vertical.

One of the devices for increasing the reading of the scale is shown in Figure 2, and was invented by Mr. Barrus, of Boston.

It consists of two vessels of the same or different sizes, x and z, having each a nipple on the lower side.

The vessel x is open at the top to the air, while the vessel z is closed on top, but has a plug in it by which it can be opened to the air. From the side of z a small pipe projects, to which is attached the rubber tubing from the chimney.

The whole apparatus is mounted on a stand in such a way that the inside of the vessels x and z are vertical.

The nipples on the bottoms are connected by means of a **U** tube of glass, which has on one side of it a scale, as shown.

The vessel z and the **U** tube are partly filled, as shown, with alcohol colored with aniline, while the vessel x and the rest of the tube have a light oil of nearly the same specific gravity as the diluted alcohol in it.

The plug being put in the vessel z and connection made with the chimney, the line of separation between the alcohol and oil, being clearly defined, will travel down the tube.

The scale on the tube may be marked in inches and the calculations made afterwards for the equivalent draft in inches of water, or the calculations may be made beforehand and the tube graduated in inches of draft.

If there is much difference in the specific gravity of the liquids used, or if they vary much from unity, they must be taken account of in making the calculations.

In the following formula a = inches difference of level in tube.
s = specific gravity of liquid in z referred to water.
s_1 = ditto for that in x.
d = area of cross-section of glass tube.
z = area of cross-section of vessel z.
x = " " " " " x.
$p - p_1$ = difference of pressure in chimney and outside, or draft in inches of water, and we have:

$$p - p_1 = a\left\{(s - s_1) + d\left(\frac{s}{z} + \frac{s_1}{x}\right)\right\}$$

It will be seen from this that if s and s_1 are each equal to, or nearly equal to unity, the formula becomes draft in inches of water = inches difference of level in tube

$$x \left\{ \frac{1}{x} + \frac{1}{z} \right\}$$

To graduate the tube in inches of draft each division should be

$$\frac{1}{s - s_1 + d \left\{ \frac{s}{z} + \frac{s_1}{x} \right\}} \text{ inches.}$$

In order to bring the liquid back to the zero point, the plug in z can be removed, or the rubber tubing disconnected.

Another device for increasing the reading of the draft gauge was made by Mr. Fisher, of the Massachusetts Institute of Technology, and is shown in Figure 3.

The whole apparatus rests on a wooden base to which it is firmly attached.

It consists of two chambers, a and b, made as follows: b is a cylindrical vessel with a metal bottom, having a rubber diaphragm across the top, which is held in place by an annular ring fastened to a flange at the top of the cylinder. From one side a pipe extends, having a three-way cock (not shown) in it. This pipe is connected with the rubber tubing spoken of before, from the chimney.

The three-way cock is used so that the interior of it is connected either with the chimney or the air, or at will.

The diaphragm has two small brass plates in its centre connected with each other by means of a brass rod, having set nuts above and below.

The upper end of the brass rod screws into a cross-head, which carries on its ends two side rods (one only shown) which connect with a similar brass cross-head above the chamber a.

The chamber a is carried on two supports above the chamber b, these supports being attached to the annular ring holding down the rubber covering of b.

The top of a is covered in exactly the same manner as b, excepting that a gland is used instead of an annular ring to hold the diaphragm in place. The rod, rising from the centre of the diaphragm, screws into the second cross-head, spoken of above, thereby connecting the centres of the diaphragms of a and b.

From the side of a, a pipe extends nearly to the vertical wooden piece which is attached to the wooden base. A quarter turn is screwed to the end of this pipe, and has above it a screw gland, carrying a vertical glass tube.

The chamber a, the pipe extending from it, and the glass tube, are filled with water (colored), and on the upright wooden piece a scale is fastened (not shown), which may be inches, or inches of draft, as desired.

The pipe from b being attached to the chimney, the vacuum in the chimney acts on the rubber diaphragm at the top of b, and the effect is carried through the cross-heads and side rods to the diaphragm over a, and this pressure on a causes the water in the glass tube to rise.

In filling the chamber a with water, care must be taken that no air is lodged in it, and that all the joints are air and water tight.

The rise of water in the glass tube is proportional directly to the area of a and inversely to the area of b, and the draft in the chimney is approximately equal to $\frac{a}{b} \times$ rise of liquid in the tube.

In using an apparatus of this kind it should be calibrated, or its accuracy first determined by comparing it with some other apparatus intended to do the same work.

Another device intended to measure chimney draft is shown in Figure 4, and is the invention of Professor J. Burkitt Webb, of Cornell.

A pair of scales or balances are set level and carry on one side a flat board of some hard wood, having a circular groove cut in its upper side.

This groove is of nearly the depth of the board and, when in use, is filled with mercury. Over this board a funnel-shaped apparatus is held in such a position that, while its edge dips into the mercury, it never touches the board. (In the figure the board and funnel are separated.)

The top of the funnel is screwed into a T, from one side of which a pipe connects with the chimney, and the other side is closed by a plug.

The method of using it is as follows: The groove in the board

being filled with mercury and the edge of the funnel dipping into it, the plug in the T is taken out and the scales balanced.

The plug being replaced and connection made with the chimney, the scales are again balanced. The difference in weight is the weight lost because of the vacuum in the chimney.

This divided by the area of the mouth of the funnel in square inches is the loss per square inch.

If the loss is in ounces, and as one ounce is 1,728 cubic inches, the equivalent draft in the chimney is—

Total loss of weight in ounces ÷ area of mouth of funnel in square inches and × 1,728.

If the funnel is made of tin and heavily coated with shellac it will work as well as though made of some metal that would not amalgamate with the mercury.

XXVI.

ENLARGEMENT OF THE EAST MAHANOY TUNNEL, E. M. R. R., SCHUYLKILL CO., PA.

By P. A. Taylor, Member of the Club.

Read December 20th., 1884.

The East Mahanoy Railroad is a branch of the Philadelphia and Reading Railroad, of which it is a very important feeder. It commences at East Mahanoy Junction and terminates at Waste House Run, in the Mahanoy Valley, a distance of about eight miles. It runs through the Broad Mountain by a tunnel 3,411 feet long, the construction of which was completed during the year 1862.

In the spring of 1876 it was decided by the Philadelphia and Reading Railroad Company to enlarge it, on account of it being too low to permit the passage of engines having the standard height of smoke stack adopted by the Company. The stacks of all engines running through the tunnel had to be cut down, and as the Philadelphia and Reading Railroad Company were desir-

ous of having all their engines of a uniform height, the enlargement was made.

To do the work it was first thought that a sufficient amount of the roof could be taken off, but on account of slips and rocks falling, caused by the cutting through several of the coal measures, when driving the tunnel, this was particularly dangerous, and necessitated timbering in some places; the risks also of detaining trains, by having the necessary false works in the tunnel to reach the roof, was great, and, the coal trade being particularly brisk at that time, the idea was abandoned, and it was then decided to take out the bottom, a portion of one side, and a part of the bench that had been left in originally by the East Mahanoy Railroad Company.

The work was started on May 29th, 1876, and finished September 9th of the same year, costing about $41,000.

The length taken out was 3,411 feet; average depth, two feet; and width, twelve feet—all of which was through conglomerate rock, known only in the anthracite region. In addition to taking out the bottom, various points of the roof had to be taken down, as well as of the sides of the tunnel, as noted above.

A force of about 225 men was employed in the work, one-half working during the day, drilling holes for the blasts, and getting everything ready for the explosion of the shots, which generally took place about ten o'clock at night, after the fast Centennial Express had passed through. The night force was employed in blasting. Number two dynamite was used, and 100 shots put off at one time by electricity. The debris was then cleared away and the track blocked up to allow trains to pass through. From ten o'clock until two o'clock, during the night, was the only time that trains entirely ceased to run through the tunnel.

The work was first put under contract to the late Philip Steinbach, of Schuylkill County, who lost on the work. The Philadelphia and Reading Railroad Company paid him his losses, and directed the work to be done by Mr. H. K. Nichols, Resident Engineer at that time, now Chief Road-Master. The writer was an assistant of Mr. Nichols, and had charge of the details under his direct supervision.

We labored under great disadvantage for the want of proper

ventilation. The shafts which had been sunk during the construction of the tunnel had been filled up for some years, and the smoke caused by the numerous trains passing through, as well as that produced by the blasts, had to seek an outlet at the east and west ends of the tunnel. This was specially the case during the low stage of the barometer, and some days it was barely possible to do any work whatever, owing to the gases produced by the engines passing through. These points are simply mentioned to show that, with all these delays, we consider the work was done in a very short time.

During the whole progress of the work but one train was delayed, and that only five minutes, and the only accident that occurred was the killing of one laborer, caused by his falling under the small engine which was used for hauling away the small trucks loaded with debris from the tunnel.

In the grades of the original roadbed of the tunnel there was a slight adverse grade from the west end to a point about midway, causing the water percolating through the seams of the coal measures to drain partly into the Susquehanna and partly into the Delaware. Now there is a continuous grade with the trade, obviating a heavy pull of the loaded coal trains after entering the tunnel.

ANNUAL REPORT OF THE SECRETARY AND TREASURER,

FOR THE FISCAL YEAR 1884.

Presented, January 10th, 1885.

To the Officers and Members of the Engineers' Club of Philadelphia:

Gentlemen:—I have the honor to present the following statement of the receipts and expenditures for the fiscal year from January 12th, 1884, to January 9th, 1885, both inclusive.

Howard Murphy, Secretary and Treasurer, in account with
The Engineers' Club of Philadelphia.

Dr.

Balance on hand Jan. 12th, 1884,			$ 72 13
Initiation fees,			635 00
Dues, 1881, Resident,	50		
" " Non-resident,	5 00	5 50	
" 1882, Resident,	22 50		
" " Non-resident,	12 50	35 00	
" 1883, Resident,	52 50		
" " Non-resident,	32 00	84 50	
" 1884, Resident,	1570 00		
" " Non-resident,	529 92	2099 92	
" 1885, Resident,	30 00		
" " Non-resident,	14 36	44 36	2269 28
Subscriptions to Proceedings,			10 00
Sales of Proceedings, Authors,		2 12	
" " Members,		33 82	
" " Non-members,		13 72	49 66
Postage charged on Proceedings,			1 78
Advertisements, 1882,		22 00	
" 1883,		201 00	
" 1884,		236 00	459 00
Key deposits,			16 25
Sale of picture frame, at cost,			3 90
			$3517 00

Cr.

Rent to January 1st, 1885,	650 04	
Gas,	9 31	
Janitor,	24 00	
Ice,	20 40	
Picture framing, supplies and repairs in rooms,	29 88	
City Directories,	6 50	
Webster's Dictionary,	9 25	
Keys,	6 48	$ 755 86
Salary of Secretary and Treasurer,		1000 00
Proceedings, Vol. III, No. 5, balance,	252 49	
" " IV, " 1,	232 46	
" " " " 2,	227 17	
" " " " 3, on acc't,	248 82	
" " " " 4, "	48 51	
" " " " 5, "	2 30	$1011 75
Reference Book,		79 62
List of Members, June, 1884,		51 19
Printing and Stationery—Notices and Records,	177 24	
" " Miscellaneous,	70 87	248 11
Postage,		213 83
Messenger, Telegraph and Express Service,		4 49
Stenographer, $10.00, Advertising, $1.20, Duty, $1.75,		12 95
Sundries,		17 25
Cash on hand, January 9th, 1885,		121 95
		$3517 00

The following are the closely approximate assets of the Club, in addition to its library and furniture.

Cash balance Jan. 9th, 1885,	$ 121 95
Due from members to date, initiation fees and dues,	226 75
Due for advertisements,	636 00
Due for Proceedings, etc.,	34 06
	$1018 76

The unpaid bills and liabilities of which account has not yet been rendered to the Club, amount to about $194.

The above assets are, in almost every case, as good as cash, so, had we wound up our affairs at the first of this year, the total dividend would have amounted to nearly $825, or more than double the very satisfactory showing of last year.

MEETINGS.

Regular,	10
Business,	3
Special Business,	5
Total,	18

ATTENDANCE.

	1884.	1883.
Members, total,	604	394
" average,	34—	22—
Visitors,	72	37

The following table is a general exhibit of the growth of the Club, and the attendance of its members, from the beginning.

	1878.	1879.	1880.	1881.	1882.	1883.	1884.
Total Active Membership	23-47	47-81	81-113	113-169	169-205	204-244	244-363
Average " "	35	64	97	141	186	224	303
" attendance,	18±	20	19	25	22+	22—	34
Percentage of "	51 p. c	31 p. c.	20 p. c.	18 p. c.	12 p. c.	10 p. c.	11 p. c.
Total visitors.		35	12	23	33	37	72

The Board of Directors have held 12 business meetings during the year.

Continuing the Membership Table from my last Report (Vol. IV, No. 1, p. 43), we have the following:

	HON.	COR.	ACT.
Membership at end of fiscal year 1883,	3	6	244
Additions,			129
Transferred from Corresponding to Active,		1	1
			374
Deceased,			4
			370
Resignations, etc.,			7
	3	5	363

The object of this Report is the simple statement of general totals and results, but were it otherwise, nothing could be said that would intensify your sorrow for the loss, by the hand of death, of four such men as Arthur Robert Faunt Le Roy, Strickland Kneass, William Lorenz and Frederic Copeland Wootten.

The net increase of Active Membership has been $48\frac{9}{10}$ per cent.

The residence of our Active Membership is now as follows:

Philadelphia,	198
Pennsylvania, outside of Philadelphia,	82
New York,	25
Virginia,	13
New Jersey,	7
Delaware,	6
Colorado,	5
Illinois,	3
North Carolina,	2
Georgia,	2
Minnesota,	2
Missouri,	2
Vermont,	1
New Hampshire,	1
Maryland,	1
Alabama,	1
Texas,	1
Michigan,	1
Ohio,	1
Indiana,	1
Iowa,	1
Arizona,	1
Austria,	1
Japan,	1
New Zealand,	1
Brazil,	1
U. S. Colombia,	1
Guatemala,	1
	363

We have, therefore, 198 Active Members residing within, and

165 without, the city limits. $45\frac{5}{10}$ per cent of our Active Members do not now reside in Philadelphia.

Another matter of Club statistics may be of interest. We are now issuing mail matter at the rate of about 15,000 letters and packages per annum.

The following original Papers have been read before the Club during the year:—

The Resilience of Steel, by Wilfred Lewis.

Steel and Iron Railroad Ties, by William Lorenz.

Chemical Obstructions in Iron Water Pipes, by Col. William Ludlow.

Observations on the Crushing Strength of Ice, by Col. William Ludlow.

The Pocahontas Mine Disaster, by J. Godolphin Osborne.

An Economical Form of Bridge Truss, by Thomas M. Cleemann.

Ths Effect of Sea Water on Iron, as Exhibited at Brandywine Lighthouse, Delaware Bay, by Edward Parrish.

Rapid Transit, by Prof. L. M. Haupt.

Removing Condemned Machinery by Dynamite, by J. J. de Kinder.

An Improvement upon the Ege-Walter Protractor, by A. E. Lehman.

The Brown Hematite (Limonite) Ores of the Siluro-Cambrian Limestone, No. II, of Centre Co., Pa., by E. V. d'Invilliers.

Utilizing Steam of the Higher Pressures, by Horace See.

Brief Description of the Anthracite Coal Fields of Penna., by C. A. Ashburner.

The Means Employed in Repairing Belmont Submerged Main at Phila., by J. J. de Kinder.

The Strength of Wrought Iron Columns, (Continuation), by Thomas M. Cleemann.

A Floating Coffer Dam, by Edwin F. Smith.

The Kaolin Beds of Chester Co., Pa., and Newcastle Co., Del., by Graham Spencer.

English Centrifugal Pumps, by Edw. I. H. Howell.

The Adaptation of Movable Dams to the Ohio and other Rivers of the U. S. as Practiced by the U. S. Corps of Engineers, by Prof. L. M. Haupt.

The Future of Locomotive Building, by Geo. S. Strong.

The Navigation of the Air, by Russell Thayer.

Measuring Chimney Draft, by H. W. Spangler.

The Enlargement of the East Mahanoy Tunnel, Schuylkill Co., Pa., by P. A. Taylor.

The following contributions have been made to the Club Reference Book:

On Finding the True Meridian, by Prof. W. S. Chaplin.

Vulgar Fractions of 1 in. Reduced to Exact Decimals of 1 in., by Howard Murphy.

Tables of Turnouts from Tangents and Inside of Curves, by Theodore Low, C. E. (Correspondent).

Table of Approximate Numbers to Facilitate Multiplication and Division, by Frederic Graff.

Some Properties of Numbers, by W. G. Neilson.

Spring of Rails in Inches; Chord 10 ft. Long, by Edw. Samuel.

Table of Wheel Bases for Turntables, by Edw. Samuel.

A Co-ordinate Method of Ascertaining Distances in Cities, Applied to Phila., by John H. Dye.

Relative Elevations of Certain Leveling Data, by Howard Murphy.

Relative cost of Haulage in the Anthracite Mines of Penna., by Mules and Locomotives, by A. W. Sheafer.

Notes on the Blue Process, by R. W. Jones.

Formulæ for Frogs and Switches, by Robert P. Snowden.

Copying Drawings in Blue Lines upon White Ground, by A. H. Haig.

The following Notes and Communications have been presented:

Cold Drawn and Polished Shafting, by Edw. I. H. Howell.

Ancient Ship Found Near Sandefjord, Norway, by H. C. Lüders.

Rolled and Annealed Phosphor-Bronze, by H. C. Lüders.

Experiments upon Relative Elasticity of Iron and Steel Structural Shapes, by Percival Roberts, Jr.

A Wire Truss Railway, by C. J. Quetil (Visitor).

The Proposed Market St. Bridge, Phila., by J. Milton Titlow.

A New Process for the Manufacture of Portland and other Hydraulic Cements, and for the Utilization of Granulated Ores, by E. F. Loiseau.

The Use of Aneroids in Leveling, by C. A. Ashburner.

The Exhaust Injector, by Edwin Ludlow.

Lateral Systems for Iron Pratt Truss Highway Bridges, by Prof. J. A. L. Waddell.

The Chicago Cable Railways, by C. A. Ashburner.

The Triangulation in Penna. by the U. S. C. and G. Survey, by Prof. Mansfield Merriman.

Formulæ for Switch Calculation, by R. P. Field.

The Establishment of a True Meridian in Phila., by C. Henry Ott.

Ancient Mining Books, by Israel W. Morris.

An Atmospheric Elevator, by Henry G. Morris.

Seamless Copper Tubing, by Henry G. Morris.

The New Parlor Cars of the Penna. R. R., by John T. Boyd.

Powers' Disinfecting Tank and Automatic Syphon, by Edward Parrish.

A Casting of a Toad, by W. L. Simpson.

A Cushioned Pier and Rolling Trunnion Drawbridge, by S. N. Stewart.

The Penna. Schuylkill Valley R. R. Bridge at Manayunk, by J. Foster Crowell.

A Three-throw Point Switch Operated from a Single Stand, by A. R. Roberts,

A River or Current Motor, by S. N. Stewart.

Old Wooden Water Pipe, Phila., by C. Henry Roney.

Notes Upon the Report of the Gun Foundry Board, by William G. Neilson.

Topographical Model of Jones Iron Ore Mine, Berks Co., Pa., by J. H. Harden.

Pope's "Treatise on Bridge Architecture," by Samuel Rea.

The Action of Water in the Modern Turbine, by William H. Ridgway.

A Simple Crane, and an Elevator, by William H. Ridgway.

The American Sectional Underground Conduits, as Laid in Phila., by C. Henry Roney.

The New Steel Boilers of the Phila. Water Dept., by J. E. Codman.

The Topography of McKean Co., Penna., by C. A. Ashburner.

A Gravity Elevated Railway, by S. N. Stewart.

A Portable Storage Battery for Mining and Exploring Purposes, by C. Henry Roney.

The Thompson Indicator, by William L. Simpson.

Fire Protection of Mills, by W. Bugbee Smith.

Hills' Map of Phila., 1796, by Samuel L. Smedley.

A Rail Joint, by Francis Lightfoot (Visitor).

Electrical Photographs of the Kohinoor Colliery Mine Workings, by A. W. Sheafer.

The Maps of the Anthracite Coal Fields of Penna., by C. A. Ashburner.

The Keeley Motor, by Capt. O. E. Michaelis.

Mr. William Astor's New Steam Yacht, by John Haug.

The Steam Yacht "Magnolia," by Fairman Rogers.

Drawing Boards, by Theodore Bergner.

A Transit Rod, by Allen J. Fuller.

An Anthracite Passenger Engine, by R. H. Soule.

The Removal of the West Phila. Stand Pipe, by W. Bugbee Smith.

Roe's Surveyors' Steel Tape and Reel, by Col. William Ludlow.

Gas Engine Indicator Cards, by A. A. Stevenson.

Appliances for Switching and Crossing Intersecting Lines of Cable Roads, by Mr. Ramsden (Visitor).

Wooden Water Pipe Laid by Stephen Girard in 1834, in Schuylkill Co., Pa., by P. A. Taylor.

Photographs of Track of Mexican National Railway, by C. A. Merriam.

A One Hundred Feet Turntable, by John C. Trautwine, Jr.

Our exchange list now comprises the following:

American Societies.

American Society of Civil Engineers.

American Institute of Mining Engineers.

American Iron and Steel Association.

Franklin Institute.

Essayons Club.

Boston Society of Civil Engineers.

Philadelphia Social Science Association.
Engineers' Club of St. Louis.
Western Society of Engineers.
Rensselaer Society of Engineers.
Civil Engineers' Club of Cleveland.
American Philosophical Society.
Engineers' Society of Western Pennsylvania.
U. S. Association of Charcoal Iron Workers.
Association of Engineering Societies.
Denver Society of Civil Engineers.
American Society of Mechanical Engineers.
Master Car Builders' Association.
American Shipmasters' Association.
International Institute for Preserving and Perfecting Weights and Measures.

Societies of Great Britain.

Institution of Civil Engineers.
Society of Arts.
Society of Engineers.
Aëronautical Society of Great Britain.
Institution of Civil Engineers of Ireland.
North of England Institute of Mining and Mechanical Engineers.
Historical and Scientific Society of Manitoba.
Association of Dominion Land Surveyors.

Continental Societies.

Portugese Society of Civil Engineers.
Swedish Society of Engineers.
Imperial Technological Society of St. Petersburg.
Austrian Society of Engineers and Architects.
Saxonian Society of Engineers and Architects.
Society of Civil Engineers, Paris.
Society of Architecture, Stuttgart, Germany.
Norwegian Association of Engineers and Architects.

South America.

Argentine Scientific Society.

American Journals.

American Architect and Building News.
American Gas Light Journal.
Army and Navy Journal.
Engineering News.
Iron Age.
Metal Worker.
American Manufacturer and Iron World.
Railroad Gazette.
Railway Age.
Railway World.
Railway Review.
Scientific American.
Van Nostrand's Engineering Magazine.
Manufacturer and Builder.
Engineering and Mining Journal.
American Engineer.
United Service.
Brick, Pottery and Glass Journal.
Leffel Mechanical News.
Mechanical Engineer.
Sanitary Engineer.
Mechanics.
Carpentry and Building.
American Machinist.
Science.
Sanitary News.
Electrician.
American Journal of Railway Appliances.
Progressive Age and Water Gas Journal.

Journals of Great Britain.

Building News and Engineering Journal.
Engineering.
Telegraphic Journal and Electrical Review.
Ironmonger and Metal Trades Advertiser.
Railway Times.

Canadian Magazine of Science and Industrial Arts.
Reference List of Railways of U. S.

Continental Journals.

Annales des Ponts et Chaussées.
O Constructor.
Nouvelles Annales de la Construction
Portefeuille Économique des Machines.

Miscellaneous American Exchanges.

Library Company of Philadelphia.
F. W. Christerns' Monthly Bulletin.
School of Mines, Columbia College.
United States Patent Office Library.
Academy of Natural Sciences.
University of Pennsylvania Library.
Boston Public Library.
Engineer Department U. S. Army.
United States Coast Survey.
Geological Survey of Indiana.
Smithsonian Institution.
Lehigh University Library.
Massachusetts Institute of Technology.
United States Geological Survey.
Second Geological Survey of Pennsylvania.
Navy Department Library.
Department of Internal Affairs of Pennsylvania.

Miscellaneous Foreign Exchanges.

Bulletin Mensuel de la Librairie Francaise.
Department of Harbors, Montreal, Canada.
McGill University, Montreal, Canada.
University of Tokio, Japan.
Geological Survey of Canada.

Respectfully submitted,

HOWARD MURPHY,
Secretary and Treasurer.

Table of Turnouts—Page A.

TABLE OF TURNOUTS FROM TANGENTS AND INSIDE OF CURVES.

THEODORE LOW, C. E., Correspondent, May 17th, 1884.

No. of Frog.		4	5	6	7	8	9	10	11	12
ANGLE OF FROG.		14° 15′	11° 25′	9°32′	8°10′	7° 09′	6° 22′	5° 43′	5° 12′	4° 46′
FROG DISTANCE.		37.9	47.3	56.6	66.1	75.4	84.7	94.1	103.7	113.0
RAD. OF TURNOUT.		150.7	235.4	339.0	461.4	602.7	762.8	941.7	1139.4	1356.0
DEGREE OF CURVE.		38° 45′	24° 32′	16° 58′	12° 26′	9° 31′	7° 31′	6° 06′	5° 02′	4° 14′
MIDDLE ORDINATE.		1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
MAIN	Radius of Turnout.	146.6	226.2	319.2	432.7	544.5	672.1	808.9	951.4	1095.7
LINE	° of Curve.	39° 53′	25° 32′	18° 02′	13° 16′	10° 32′	8° 32′	7° 05′	6° 02′	5° 14′
1°	Middle Ordinate.	1.21	1.22	1.24	1.25	1.29	1.33	1.37	1.41	1.45
CURVE.	Central Angle M. Line.	22′	28′	34′	40′	46′	50′	56′	1° 02′	1° 08′
MAIN	Radius of Turnout.	143.0	217.6	302.2	403.2	498.3	602.3	709.2	815.9	918.8
LINE	° of Curve.	40° 56′	26° 34′	19° 02′	14° 14′	11° 31′	9° 32′	8° 05′	7° 02′	6° 14′
2°	M. Ord.	1.24	1.27	1.31	1.34	1.42	1.49	1.56	1.64	1.73
CURVE.	Cen Ang. M. L.	44′	56′	1° 08′	1° 20′	1° 30′	1° 40′	1° 52′	2° 04′	2° 16′
MAIN	Radius of Turnout.	139.3	209.6	286.9	375.7	457.6	543.5	631.3	714.2	791.2
LINE	° of Curve.	42° 04′	27° 36′	20° 04′	15° 18′	12° 33′	10° 34′	9° 05′	8° 02′	7° 15′
3°	M. Ord.	1.27	1.32	1.38	1.43	1.55	1.65	1.75	1.87	2.01
CURVE.	Cen Ang M. L.	1° 08′	1° 24′	1° 42′	2°	2° 16′	2° 32′	2° 48′	3° 06′	3° 24′
MAIN	Radius of Turnout.	136.0	202.2	273.0	353.7	423.1	495.2	566.9	635.0	694.6
LINE	° of Curve.	43° 08′	28° 38′	21° 06′	16° 16′	13° 34′	11° 36′	10° 08′	9° 02′	8° 15′
4°	M. Ord.	1.30	1.37	1 45	1.53	1.67	1.80	1.94	2.11	2.29
CURVE.	Cen Ang. M. L.	1° 30′	1° 52′	2° 16′	2° 38′	3° 02′	3° 24′	3° 46′	4° 08′	4° 32′

MAIN	Radius of Turnout.	132.7	195.3	260.4	333.0	394.6	456.2	516.0	571.6	619.1
LINE	° of Curve.	44° 16′	29° 40′	22° 08′	17° 16′	14° 34′	12° 36′	11° 08′	10° 02′	9° 16′
5°	M. Ord.	1.33	1.42	1.52	1.62	1.79	1.96	2.13	2.34	2.57
CURVE.	Cen. Ang. M. L.	1° 52′	2° 20′	2° 50′	3° 18′	3° 46′	4° 14′	4° 42′	5° 10′	5° 40′
MAIN	Radius of Turnout	129.6	188.3	249.0	314 7	368.6	422.9	473.5	519.8	560.0
LINE	° of Curve.	45° 22′	30° 48′	23° 10′	18° 17′	15° 36′	13° 35′	12° 08′	11° 02′	10° 15′
6°	M. Ord.	1.36	1.47	1.59	1.71	1.91	2.12	2.32	2.57	2.85
CURVE.	Cen. Ang. M. L.	2° 16′	2° 50′	3° 24′	3° 58′	4° 32′	5° 04′	5° 38′	6° 12′	6° 46′
MAIN	Radius of Turnout.	126.8	182.3	238.5	299.0	346.3	393.0	437.5	476.5	509.9
LINE	° of Curve.	46° 26′	31° 50′	24° 12′	19° 15′	16° 36′	14° 37′	13° 08′	12° 02′	11° 15′
7°	M. Ord.	1.39	1.52	1.66	1.81	2.03	2.27	2.51	2.81	3.12
CURVE.	Cen. Ang. M. L.	2° 38′	3°18′	3° 58′	4° 36′	5° 16′	5° 56′	6° 34′	7° 14′	7° 54′
MAIN	Radius of Turnout.	124.1	176.7	229.3	284.1	327.0	368.0	406.5	439.9	469.1
LINE	° of Curve.	47° 30′	32° 52′	25° 12′	20° 16′	17° 36′	15° 37′	14° 08′	13° 02′	12° 14′
8°	M. Ord.	1.42	1.57	1.73	1.90	2.15	2.42	2.70	3.04	3.39
CURVE.	Cen. Ang. M. L.	3°	3° 46′	4° 30′	5° 16′	6°	6° 46′	7° 30′	8° 16′	9°
MAIN	Radius of Turnout.	121.4	171.4	220.4	270.6	308.9	346.0	379.7	408.5	433.4
LINE	° of Curve.	48° 38′	33° 56′	26° 14′	21° 18′	18° 38′	16° 37′	15° 08′	14° 04′	13° 15′
9°	M. Ord.	1.45	1.62	1.80	1.99	2.27	2.57	2.89	3.27	3.66
CURVE.	Cen. Ang. M. L.	3° 22′	4°14′	5°04′	5° 56′	6° 46′	7° 36′	8° 26′	9° 18′	10° 08′
MAIN	Radius of Turnout.	118.8	166.4	212.1	258.9	293.4	326.5	356.2	381.4	402.8
LINE	° of Curve.	49° 46′	34° 58′	27° 16′	22° 16′	19° 37′	17° 37′	16° 08′	15° 04′	14° 16′
10°	M. Ord.	1.48	1.66	1.87	2.09	2.40	2.73	3.09	3.50	3.94
CURVE.	Cen. Ang. M. L.	3° 46′	4° 42′	5° 38′	6° 34′	7° 30′	8° 26′	9° 22′	10° 20′	11° 16′

Table of Turnouts—Page B.

RELATIVE ELEVATIONS OF CERTAIN LEVELING DATA.

HOWARD MURPHY, June 21st, 1884.

These were carefully compiled from accurate official data. They may be found useful, not only in Philadelphia, but wherever the railroad elevations are extended.

10.48=Exceptionally high water in Delaware River, at Phila., on Oct. 23d, 1878. The "Neck" meadows were flooded.

8.732=Phila. City Base ("City Datum").

8.100=Permanent Bench Mark of U. S. Coast Survey on Granite Block at Gloucester Point, opposite Phila.

6.913=Pennsylvania Railroad Base.

6.484=High Tide in Delaware River, at Phila.

3.517=Phila. & Reading R. R. Base.

3.349=Mean Tide in Delaware River, at Phila.

0.214=Low Tide in Del. Riv., at Phila.

0=Mean Surface of Atlantic Ocean at Raritan Bay.

NOTES AND COMMUNICATIONS.

A GRAVITY ELEVATED RAILWAY.

Business Meeting, October 4th, 1884.—Mr. S. N. Stewart presented the following:—

Some new features in railways (a raised landing and a compound wheel,) are especially adapted to elevated roads—greatly diminishing the cost and removing most of the objections hitherto urged against such roads.

No locomotives used, hence there are no ashes, cinders or smoke to annoy passengers or passers. The cars may be almost noiseless. The absence of locomotives and the running of very light cars singly, instead of in trains, permits a light, cheap road, yet one of great capacity.

That part of the track in front of the station is raised sufficiently above the general level, that a car, instead of relying on brakes, which cause great waste of power and wear, checks itself by *running up an incline and stopping upon a higher level.*

A higher level is a reservoir of power—the simplest possible accumulator—and when the car starts, the force of the descent sends it off at full speed, obviating loss of time and expenditure of power in getting up speed. At present nearly as much power is lost on city elevated railroads by frequent stoppages as is utilized in propulsion.

On ordinary steam railroads the raised landings would only be at principal stations, and be only of sufficient height to furnish about nine-tenths the resistance necessary to stop an average train, one-tenth being supplied by brakes, but on elevated roads where locomotives may be dispensed with, the raised landing is made high enough to impart a momentum which will send a car, say one-half mile, and part way up another incline at another station, where it catches, and is drawn to the top of the incline by a small stationary engine, or by stored power of any kind. By the use of compound wheels the friction is so slight that a fall of a few feet is sufficient for a half-mile run.

Dispensing with locomotives on elevated roads means much. Locomotives must be very heavy to secure adhesion on wet rails, and every part of the road must be heavy enough to sustain the locomotive. This compels an investment far greater than would otherwise be necessary.

Locomotives are extremely costly in construction and enormously wasteful of fuel, while the power which they expend in pulling their own heavy weight is a dead loss of one hundred cents on the dollar; moreover, the moving friction of a locomotive is 15 pounds to the ton, while that of the train is only 6 pounds to the ton. 'Tis true that notwithstanding all this they, in New York City, haul a passenger ten miles for five cents, but a gravity road can carry him for three cents.

The small stationary engines for all the stations of a ten-mile road would not cost as much as one locomotive. If any objections to small steam engines, power may be obtained from storage batteries or compressed air, or gas engines, or water from the city pipes, or a portable engine may pass along the street twice a day and wind up weights or compress springs at stations.

It will be noted that no conductor, brakeman or other employee is necessary upon a gravity car (tickets being collected at stations), and it is obvious that better time can be made

than on any other road: first, because the car gets full speed from the start; second, it can be stopped quicker without shock to passengers, because the retardation is steady —no jerks as with brakes; third, the center of gravity can be lower than is possible with a locomotive. With a low-down body it is next to impossible for a car to leave the track. Such is the stability of the low-down suspension body that a car 8 feet wide can be run on a 2 ft. gauge with absolute safety.

Gravity roads offer to the rich and poor all the advantages of a country home with quick, cheap and pleasant conveyance to the center of the city.

While the horse car is too slow for those living far out, the ordinary steam road cannot offer frequent stations nor frequent trains, everything being on too large a scale for local convenience, but the gravity road, with frequent stations and frequent cars, can push five miles out of the city, buying the land and making its line a continuous town.

The ability of the gravity road to run cars singly as cheaply as in trains, is perhaps its greatest advantage over the locomotive road. It will draw more travel because the passenger knows he can get a car almost any minute. There are not many streets in the world where it will pay to run a locomotive often enough to catch the majority. People not living far out take the horse roads rather than wait.

With noise, cinders, smoke and ashes banished, few will consider a light and pretty skeleton structure occupying but a small strip in the middle of the roadway, in any way objectionable, and even if the fanciful disadvantages were real, the quick time and low fares would be a tenfold compensation.

Many thousands of salesmen, mechanics and laborers will tell you, "I go to my work at 7 or 8 o'clock and leave at 6. At those hours two-thirds of the horse car passengers must stand—a surging mass of miserable men. Standing 30 or 40 minutes twice a day upon the horse car is the most disagreeable part of my day's work. If men in authority had no carriages and had to ride on the horse cars during the crowded hours, they would have granted right of way to elevated roads long ago." Even if the fare were ten cents instead of five, the mechanic who lives far out would rather work one-half hour per day more to earn that ten cents than ride on the horse car free, for he would still get home sooner and get a refreshing ride in place of a tedious drag.

In New York rapid transit has drawn scores of thousands of inhabitants and added millions of dollars to the real estate valuation.

Elevated roads open the way to other improvements by awakening enthusiasm and encouraging progressive men.

The gravity road is something like the Russian slide, but the Russian slide is merely two inclines facing.

The wheel which, for lack of a better word is called a compound wheel, is a hollow wheel with interior wheels upon which the axle revolves. When these interior wheels are five times the diameter of their axles it is obvious that nearly four-fifths the friction is removed. Hence, with such wheels upon the passenger or freight cars, the same locomotive can pull a much longer train; or lighter locomotives be used, which lighter locomotives would permit the use of lighter rails, lighter bridges, etc. Any engineer who understands the principle of anti-friction rollers will understand the compound wheel.

ELECTRIC PHOTOGRAPHS OF THE KOHINOOR COLLIERY WORKINGS.

Special Business Meeting, November 1st, 1884.—Mr. Arthur W. Sheafer presented the following:—

It gives me great pleasure to send the Club a number of the electric photographs of the Kohinoor Colliery mine workings, recently taken for Mr. J. Temple Brown, of the Smithsonian Institution, to illustrate, at the New Orleans Exposition, the mines and mining methods of the anthracite coal regions. They are, as far as I can learn, the first photographs of underground mine workings taken in Pennsylvania.

This colliery, situated in the borough of Shenandoah, Schuylkill County, is operated by the Philadelphia and Reading Coal and Iron Company, and it was through the courtesy and assistance of its officials, of Mr. Bretz, the photographer, and of Mr. Richard C. Kear, of the Pennsylvania Arnaux Electric Light Company, that the plates were obtained.

A day or more was occupied in making connections with the compressed air pipes, hanging lamps, running wires and other necessary preparations. The photographs were taken August 28th.

With the exception of No. 21,935, the plates were exposed for thirty (30) minutes, and this explains the blurred appearance of the figures in Nos. 21,936 and 21,942. No. 21,935 was exposed twenty minutes. In No. 21,936, five lamps were used; two, ten feet in front of the men, and three, thirty-five feet behind them.

The mammoth bed at this point is separated, by twenty-five feet of rock, into two members, of respectively 17 and 26 feet in thickness, in the latter of which these workings are located. The photographs show but 12 to 15 feet of the coal, except in Nos. 21,935 and 21,940, where the range is considerably more. The various benches or subdivisions of the bed, as well as the vertical partings due to crush, are very plainly shown.

ANTHRACITE ENGINE NO. 24, N. Y., W. S. & B. R. R.

Regular Meeting, November 15th, 1884.—Mr. R. H. Soule presented the following, illustrated by photograph:

There are 30 eight-wheeled engines of this class on this road, the principal dimensions being as follows:

Cylinders,	18 in. diam.	Number of tubes,	188.
Stroke,	24 in.	External diameter of tubes,	2 in.
Diameter of drivers,	68 in.	Length of tubes between sheets,	10 ft. $10\frac{5}{8}$ in.
" " paper truck wheels,	33 in.	External heating surface of tubes,	1084 sq. ft.
" " paper tender wheels,	42 in.	Total heating surface boiler,	1212 sq. ft.
Spread of drivers,	8 ft. 6 in.	Weight on engine truck with boiler filled,	32,000 lbs.
Total wheel base, engine proper,	22 ft. $9\frac{3}{8}$ in.	Weight on main wheels,	32,500 "
Length over all engine and tender,	57 ft. $9\frac{3}{8}$ in.	Weight on trailing wheels,	31,500 "
Outside diameter, smallest ring of boiler,	55 in.	Total weight on drivers,	64,000 "
Length of fire-box,	10 ft. $\frac{3}{8}$ in.	Total weight of engine,	96,000 "
Width of fire-box,	3 ft. $4\frac{1}{2}$ in.	Water capacity of tender,	3000 gals.
Area of grate,	34 sq. ft.	Coal capacity of tender,	5 tons.
		Weight of tender empty,	34,000 lbs.
		Weight of tender loaded,	64,000 "

This engine, designed by Mr. Howard Fry, formerly Supt. M. P. of the West Shore Road, is conspicuous particularly for its massiveness and its very utilitarian appearance, the use of all unnecessary mouldings or trappings in its finish having been studiously avoided. The engine presents a very sombre appearance, there being no brass work used for ornamentation and only a limited use of brass for small parts, principally inside the cab. The domes are patterned on English practice, likewise the stack, which has no cast iron about it whatever. The cab is very commodious, much larger than usual for this class of engine. The truck wheels and the tender wheels are of paper, made by the Allen Paper Car Wheel Co.

The performance of these engines has been excellent, and on the Mohawk Division they have proved themselves to be a much better engine for winter service than the bituminous engine of the same general type and proportions. This difference is principally due to the fact that the fire-box of the anthracite engine rests on the top of the frames raising the ash-pan higher above the track than with the bituminous engines, whose fire-boxes drop down between the frames.

WOODEN WATER PIPE LAID BY STEPHEN GIRARD IN 1834, IN SCHUYLKILL CO., PENNA.

Business Meeting, December 6th, 1884.—Mr. P. A. Taylor presented the Club with a fine specimen of this pipe accompanied by the following description:—

This wooden water pipe was taken out of the ground on the Broad Mountain, on the line of the Mahanoy and Shamokin Railroad, Schuylkill County, Pennsylvania.

The pipe was laid by the late Stephen Girard under the direct supervision of Thomas Sharp, Superintendent of the Danville and Pottsville Railroad. The work was started in the spring of 1834 and finished during the summer of the same year. The pipes were made of yellow pine logs and laid in sections, average length of each section about eighteen feet, diameter of pipe, fifteen inches, diameter of bore, three inches. It was laid from a dam, located on a small stream known as Mud Run, nearly on the summit of the Broad Mountain, for a distance of one and one-half miles to the head of Plane Number Five of the Danville and Pottsville Railroad. It was used for the purpose of conveying water to the steam engines for hoisting loaded cars from the Mahanoy Valley. The fall from dam to boilers was about forty feet. The pipe from which this specimen was taken, was dug out of the ground in 1884 by the Philadelphia and Reading Railroad Company, who had built a new dam on the same site as the old one for the purpose of giving an ample supply of water for their locomotives, stationary engines, etc., at the head and foot of Mahanoy Plane, and also for several of the collieries of the Philadelphia and Reading Coal and Iron Company in the Mahanoy Valley. They laid new cast iron pipe of ten inches diameter, and followed as nearly as possible the old line of wooden water pipe. The specimen was found at a depth of about five feet below the surface, in a conglomeratic soil, and when taken out had been covered up for fifty years. When cut, the specimen showed the pipe to be in a wonderful state of preservation, especially at the joints where they were connected. Sap was still in the wood.

END OF VOLUME IV.

ENGINEERS' CLUB OF PHILADELPHIA

ORGANIZED DECEMBER 17th, 1877.

LIST OF MEMBERS.

JUNE, 1884.

CLUB ROOMS:

1523 CHESTNUT STREET,

PHILADELPHIA, PA.

ENGINEERS' CLUB OF PHILADELPHIA.

ROOMS, NO. 1523 CHESTNUT STREET,

PHILADELPHIA, PA.

OFFICERS FOR 1884.

President,

COL. WILLIAM LUDLOW.

Vice-President,

J. J. DE KINDER.

Board of Directors,

T. M. CLEEMANN, FREDERIC GRAFF,
RUDOLPH HERING, WASHINGTON JONES,
HENRY G. MORRIS.

Secretary and Treasurer,

HOWARD MURPHY.

STANDING COMMITTEES OF BOARD OF DIRECTORS:

On Finance—FREDERIC GRAFF and HENRY G. MORRIS.
On Membership—HENRY G. MORRIS and J. J. DE KINDER.
On Publication—T. M. CLEEMANN and WASHINGTON JONES.
On Library—RUDOLPH HERING and T. M. CLEEMANN.

MEETINGS:

Annual Meeting—2d Saturday of January.
Regular Meetings—1st and 3d Saturdays of month, at 8 P.M.
Business Meetings—2d Saturday of January, and 1st Saturdays of March, May, October and December.
The Board of Directors meets on the 3d Saturday of each month.

LIST OF MEMBERS

WITH

ADDRESS AND DATE OF ELECTION.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

Members are particularly requested to keep the Secretary constantly informed as to their correct address.

HONORARY MEMBERS.

Haupt, Gen. Herman, April 6th, 1878.
Pres. Dakota and Great Southern R. R.,
312 Summit Ave., St. Paul, Minn.

Robinson, Moncure, April 6th, 1878.
Civil Engineer,
1319 Spruce St., Phila.

Walter, Thomas U., Feb. 5th, 1881.
Architect,
720 N. Broad St., Phila.

CORRESPONDING MEMBERS.

Buckman, G. R., May 17th, 1879.
Colorado Springs,
Colorado.

Fletcher, Robt., April 6th, 1878.
Professor of Civil Engineering
Dartmouth College, Hanover, N. H.

Pontzen, E., Oct. 4th, 1879.
Civil Engineer,
4 Rue de Castellane, Paris, France.

Robinson, J. F., April 6th, 1878.
Supt. Atlas Works,
Manchester, England.

Schenck, A. A., Feb. 16th, 1878.
Civil Engineer,
4006 Baltimore Ave., Phila.

ACTIVE MEMBERS.

Abercrombie, F. P., June 16th, 1883.
Engineer W. Jersey R. R. Co.,
Camden, N. J.

Africa, J. Simpson, June 18th, 1881.
Secretary of Internal Affairs,
Harrisburg, Pa.

Allen, Kenneth, March 15th, 1884.
Asst. Engr. Phila. Water Dept.,
13th and Spring Garden Sts., Phila.

Ashburner, Chas. A., Dec. 17th, 1877.
Geologist in Charge Survey of the Anthracite Coal Fields,
907 Walnut Street, Phila.

Atlee, Walter, Dec. 1st, 1883.
Civil Engineer,
210 S. 13th St., Phila.

Auchincloss, W. S., March 5th, 1881.
Civil Engineer,
209 Church St., Phila.

Austin, T. Everett, Jan. 12th, 1884.
Mech. Eng. with Geo. S. Strong,
1515 N. 13th St., Phila.

Babcock, W. Irving, Jan. 14th, 1882.
Marine Engineer,
Delaware River Iron Ship Building and Eng. Works, Chester, Pa.

Baermann, P. H., March 5th, 1881.
Civil Engineer,
P. O. Box 228, West Troy, N. Y.

Baldwin, Wm. Henry, Feb. 5th, 1881.
Civil Engineer,
44 Chapin Block, Buffalo, N. Y.

Bankson, Lloyd, April 19th, 1884.
Asst. Engr. Phila. Water Dept.,
4224 Chester Ave., Phila.

Barnard, Louis H., April 7th, 1883.
Prof. Civil Engineering State College,
State College, Centre Co., Pa.

Barnes, Edward H., March 15th, 1884.
Civil Engineer,
Bedford, Bedford Co., Pa.

Barnes, Oliver W., June 16th, 1883.
Chief Engr. South Penna. R. R.,
57 Broadway, N. Y.

Beardsley, Arthur, Jan. 18th, 1879.
Professor of Civil and Mechanical Engineering,
Swarthmore College, Swarthmore, Delaware Co., Pa.

Billin, Chas. E., Dec. 17th, 1877.
With A. & P. Roberts & Co.,
261 S. 4th St., Phila.

Birkinbine, Harry, May 1st, 1880.
Chief Engineer City Water Works Co.,
Council Bluffs, Iowa.

Bixby, Wm. H., June 16th, 1883.
Capt. of Engineers, U. S. A.,
33 West Houston St., N. Y. City.

Bland, Geo. P., March 5th, 1881.
Civil Engineer,
3214 Woodland Ave., Phila.

Bonzano, Maximilian F., March 1st, 1879.
Division Road Master P. & R. R. R.,
9th and Green Sts., Phila.

Borda, Eugene, Oct. 2d, 1880.
Metallurgist and Mining Engineer,
326 Walnut St., Phila.

Boyd, John T., May 1st, 1880.
Mechanical Engineer, I. P. Morris Co.,
423 S. 15th St., Phila.

Bramwell, Geo. W., April 19th, 1884.
Div. Engr. S. V. R. R.,
Roanoke, Va.

Brendlinger, P. F., Jan. 10th, 1880.
P. A. Engineer P., McK. & Y. R. R.,
No. 77 4th Ave., Pittsburgh, Pa.

Brewer, Paul C., April 19th, 1884.
Asst. Engr. P. R. R.,
1333 N. 12th St., Phila.

Briand de Morainville, V. E., March 15th, 1884.
Civil Engineer and Architect,
215 E. Chelten Ave., Germantown, Phila.

Brooke, Walter C., May 17th, 1884.
Engr. Mineral R. R. & Mining Co.,
Shamokin, Northumberland Co., Pa.

Brosius, Milton L., Nov. 19th, 1881.
Mechanical Engineer,
Lewistown, Pa.

Brown, T. Benton, June 21st, 1884.
Asst. Engr. L. V. R. R.,
Mauch Chunk, Pa.

Bruner, Daniel P., Dec. 1st, 1883.
Manager Durham House Drainage Co.,
Room 1, Ledger Building, Phila.

Buchholz, Chas. W., May 1st, 1880.
Asst. Engineer P. & R. R. R. Co.,
227 S. 4th St., Phila.

Burnham, Geo., Jr., Dec. 17th, 1877.
Baldwin Locomotive Works,
500 N. Broad St., Phila.

Burnham, William, Dec. 17th, 1877.
Secretary and Treasurer Standard Steel Works,
220 S. 4th St., Phila.

Cabot, W. Brooks, May 17th, 1884.
Engr. Everett Iron Co.,
Everett, Bedford Co., Pa.

Cassatt, A. J., Nov. 19th, 1881.
Civil Engineer,
233 S. 4th St., Phila.

Cassin, Isaac S., June 18th, 1881.
Mechanical and Civil Engineer,
1404 N. 12th St., Phila.

Chance, Dr. H. Martyn, Dec. 6th, 1879.
Mining Engineer,
2433 Fairmount Ave., Phila.

Chamberlain, Edwin, June 21st, 1884.
Div. Roadmaster P. & R. R. R.,
329 N. 6th St., Reading, Pa.

Chaplin, W. S., Jan. 14th, 1882.
Professor of Mathematics
Union College, Schenectady, N. Y.

Chauvenet, S. H., Jan. 18th, 1879.
Res. Engr. S. Pa. R. R.,
Ray's Hill, Bedford Co., Pa.

Christie, James, March 15th, 1884.
Mech. Engr. Pencoyd Iron Works,
Pencoyd, Pa.

Church, J. B., July 1st, 1882.
Supt. Alliance Coal Mining Co.,
Pottsville, Pa.

Church, W. S., July 1st, 1882.
Asst. Engineer Department of Parks,
46 W. 9th St., N. Y. City.

Clarke, H. W., April 7th, 1883.
Engineer in charge N. Y. & Pa. State Boundary Survey,
11 Granger Block, Syracuse, N. Y.

Clarke, Thos. C., Feb. 2d, 1878.
Union Bridge Co.,
52 Wall St., New York City.

Cleemann, Thos. M., (*Director*), April 20th, 1878.
Civil Engineer,
2135 Spruce St., Philadelphia.

Clement, F. H., Jan. 14th, 1882.
Div. Engineer S. Penna. R. R.,
Everett, Bedford Co., Pa.

Cloud, John W., June 21st, 1884.
Engr. of Tests, P. R. R.,
P. O. Box 655, Altoona, Pa.

Codman, John E., Jan. 18th, 1879.
Asst. Engineer Phila. Water Department,
13th and Spring Garden Sts., Phila.

Coe, W. W., May 6th, 1882.
Chief Engineer N. & W. R. R. and S. V. R. R.,
Roanoke, Roanoke Co., Va.

Cofrode, Jos. H., March 5th, 1881.
Bridge Builder,
257 S. 4th St., Phila.

Collins, T. Earl, Jan. 8th, 1881.
Mechanical Engineer,
St. Elmo, Chaffee Co., Colorado.

Colton, O. B., Dec. 17th, 1877.
Civil Engineer with Wilson Bros. & Co.,
243 State St., Chicago, Ill.

Constable, Howard, Feb. 16th, 1878.
Hydraulic Engr., Western Rep. H. R. Worthington Hydraulic Works.
414 N. 3d St., St. Louis, Mo.

Constable, Stevenson, April 2d, 1881.
Asst. Supt. American Nickel Works,
Box 44, Camden, N. J.

Converse, John H., May 17th, 1884.
Baldwin Locomotive Works,
500 N. Broad St., Phila.

Cooper, Wm. A., March 2d, 1878.
Mechanical Engineer with Alan Wood & Co.,
Conshohocken, Pa.

Cooper, Wm. B., June 18th, 1881.
Civil Engineer,
Fort Edward, N. Y.

Corlies, Franklin H., Oct. 2d, 1880.
Mechanical Engineer with Wm. Sellers & Co.,
1530 Arch St., Phila.

Coxe, Eckley B., June 21st, 1884.
Mining Engineer,
Drifton, Luzerne Co., Pa.

Cramp, Chas. H., Jan. 18th, 1879.
Ship Builder,
1736 Spring Garden St., Phila.

Cramp, Edwin S., March 5th, 1881.
Marine Engineer,
1515 Oxford St., Phila.

Cranmer, W. Clarence, Jan. 18th, 1879.
Asst. Comr. of Highways,
City Hall, Phila.

Cresson, Geo. V., Jan. 12th, 1884.
Machinist and Manufacturer,
S. E. Cor. 18th and Hamilton Sts., Phila.

Crizuka, Mataro, June 21st, 1884.
Mech. Engr., Baldwin Locomotive Works,
1236 Buttonwood St., Phila.

Crowell, J. Foster, June 16th, 1883.
Engineer of Construction P. R. R.,
309 W. Chelten Ave., Germantown, Phila.

Cruse, Arthur R., Jan. 13th, 1883.
Mechanical Engineer,
39 Laurel St., Phila.

Darrach, Chas. G., April 20th, 1878.
Civil Engineer,
Ridley Park, Pa.

Davenport, R. W., May 17th, 1884.
Supt. Midvale Steel Co.,
Nicetown, Phila.

Dawson, Edwin F., May 21st, 1881.
Civil Engineer,
513 Linden St., Camden, N. J.

Dean, F. W., March 15th, 1884.
Mech. Engr., Calumet & Hecla Min. Co.,
1057 Richmond St., Phila.

Dechant, William H., June 21st, 1884.
Div. Roadmaster P. & R. R. R.,
Tamaqua, Schuylkill Co., Pa.

DeHaven, I. Norris, May 17th, 1884.
Foreman Wm. Sellers & Co.,
527 S. 42d St., Phila.

de Kinder, Joseph J., (*Vice-President*), Dec. 6th, 1879.
Engineer and Contractor,
325 Walnut St., Phila.

Derbyshire, Wm. H., May 6th, 1882.
Mech. Engineer with Machine Tool Works,
24th and Wood Sts., Phila.

Dietz, Augustus, March 15th, 1884.
Mech. Engr., Hoff & Fontaine,
1162 N. 3d St., Phila.

Dilks, Albert W., Dec. 1st, 1883.
Architect,
1001 Chestnut St., Phila.

d'Invilliers, Camille S., May 1st, 1880.
Assistant Engineer Penna. R. R. Co.,
Philipsburg, Centre Co., Pa.

d'Invilliers, Edward V., Jan. 10th, 1880.
Assistant 2d Geological Survey of Penna.,
711 Walnut St., Phila.

Du Barry, Jos. N., June 18th, 1881.
Third Vice President Penna. R. R.,
233 S. 4th St., Phila.

Durham, C. W., June 16th, 1883.
Pres. Durham House Drainage Co.,
231 E. 42d St., N. Y.

Dye, John H., March 6th, 1880.
Registrar Phila. Survey Department,
City Hall, Phila.

Edwards, J. W., Oct. 4th, 1879.
Mining Engineer,
Delaware Ave. and Green St., Phila.

Ehlers, Peter, March 5th, 1881.
Mechanical Engineer,
170 Broadway, Albany, N. Y.

Elmer, H. N., Dec. 1st, 1883.
Civil Engineer and Building Inspector,
P. O. Box 276, St. Paul, Minn.

Estabrook, J. D., Dec. 2d, 1882.
Chief Commissioner of Highways, Phila.
Coulter St., Germantown, Phila.

Evans, Geo. M., Jan. 12th, 1884.
Engineer and Contractor,
Roanoke, Roanoke Co., Va.

Evans, L. P., May 21st, 1881.
Engineer Phila. Bridge Works,
Pottstown, Pa.

Fairfax, Henry, March 5th, 1881.
Engineer and Contractor,
Roanoke, Roanoke Co., Va.

Faunt Le Roy, A. R., June 21st, 1884.
Asst. Engr. C. M. & St. P. Ry.,
Milwaukee, Wis.

Feister, Henry P., June 16th, 1883.
Supt. Franklin Machine Works,
517 Minor St., Phila.

Ferrell, Joseph L., Oct. 2d, 1880.
Manager Southwark Foundry and Machine Works,
430 Washington Ave., Phila.

Field, Burr K., March 15th, 1884.
Supt. of Bridges,
Dept. of Highways, City Hall, Pa.

Field, Robert P., April 7th, 1883.
Mining Engineer,
435 Chestnut St., Phila.

Flickwir, D. W., May 6th, 1882.
Supt. Shenandoah Valley R. R.,
Roanoke, Roanoke Co., Va.

Francis, Harry C., March 1st, 1879.
Manager Kensington Engine Works,
Beach and Vienna Sts., Phila.

Frost, Geo. H., June 16th, 1883.
Editor "Engineering News,"
13 Tribune Building, N. Y. City.

Fuller, Allen J., July 1st, 1882.
Mechanical Engineer Phila. Water Works,
4302 Osage Ave., Phila.

Gardiner, John, June 18th, 1881.
Surveyor and Civil Engineer,
P. O. Box 255, Tucson, Arizona.

Garrett, Jesse, April 19th, 1884.
Manager Otis Bros. & Co., Elevators,
425 Walnut St., Phila.

Geer, Harvey M., June 18th, 1881.
Civil Engineer,
Ballston, N. Y.

Gerhard, Wm. Paul, March 15th, 1884.
Chief Engineer Durham House Drainage Co.,
231 E. 42d St., N. Y. City.

Gest, Alex. P., March 1st, 1879.
Asst. Engineer Pittsburgh Div. P. R. R.,
Union Station, Pittsburgh, Pa.

Graff, Frederic (*Director*), Jan. 18th, 1879.
Hydraulic Engineer,
1337 Arch St., Phila.

Graham, John, Jr., May 1st, 1880.
General Manager Camden Iron Works,
Camden, N. J.

Graham, Thomas H., Dec. 4th, 1880.
Manager Mining Co., Cuba,
400 Chestnut St., Phila.

Gray, Wm. J., May 6th, 1882.
Mechanical Engineer,
3409 Walnut St., Phila.

Gwilliam, G. T., Dec. 2d, 1882.
U. S. Asst. Engr.,
Lewes, Del.

Haig, Andrew H., Dec. 1st, 1883.
Mech. Engr. Southwark F'dy and Mach. Co.,
114 Freelander St., Phila.

Hall, Willis E., Jan. 14th, 1882.
Mech. Eng.,
P. O. Box 111, Altoona, Pa.

Hand, H. W., Jan. 12th, 1884.
Mech. Engr., I. P. Morris Co.,
1057 Richmond St., Phila.

Harden, John H., Jan. 17th, 1879.
General Mining Engineer Phœnix Iron Co.,
Box No. 4, Phœnixville, Chester Co., Pa.

Hartley, Henry J., Jan. 12th, 1884.
Supt. Smithy and Boiler Dept. Port Richard Iron Works,
1057 Richmond St., Phila.

Haswell, Chas. H., July 1st, 1882.
Civil and Marine Engineer,
29 Broadway, P. O. Box 2961, New York City.

Haug, John, Oct. 4th, 1879.
Ship and Engineer Surveyor of Lloyd's Register of Shipping, London,
206 Walnut Place, Phila.

Haupt, Herman, Jr., April 7th, 1883.
Metallurgist,
312 Summit Ave., St. Paul, Minn.

Haupt, Lewis M., Dec. 17th, 1877.
Professor of Civil Engineering University of Penna.,
34th and Locust Sts., Phila.

Heller, Chas. S., Oct. 4th, 1879.
Designer and Manufacturer of Engineers' Field Instruments,
Ridge Ave. and Spring Garden St., Phila.

Henzsey, Wm. P., May 17th, 1884.
Mech. Engr. Baldwin Locomotive Works,
500 N. Broad St., Phila.

Hering, Carl O., Jan. 14th, 1882.
Electrical Engineer,
112 N. Twelfth St., Phila.

Hering, Rudolph (*Director*), Feb. 2d, 1878.
Consulting Civil and Sanitary Engineer,
326 Walnut St., Phila.

Heston, Walter D., March 15th, 1884.
Civil Engineer,
4941 Lancaster Ave., Phila.

Hexamer, C. J., Dec. 2d, 1882.
Civil Engineer,
419 Walnut St., Phila.

Heuer, W. H., June 21st, 1884.
Major of Engineers, U. S. A.,
1125 Girard St., Phila.

Holliday, Robert L., June 21st, 1884.
Supt. Bedford Div. P. R. R.,
Bedford, Bedford Co., Pa.

Hoopes, Herman, Dec. 17th, 1877.
Civil Engineer,
609 Chestnut St., Phila.

Hoopes, John J., Oct. 16th, 1880.
Resident Engineer American Construction Co.,
West Dublin, Fulton Co., Pa.

Howell, Edward I. H., Jan. 18th, 1879.
Mechanical Engineer,
51 N. Seventh St., Phila.

Howell, Benj. P., May 17th, 1884.
Engineer of Mines, H. C. Frick Coke Co.,
Scottdale, Pa.

Hoyt, Allen V., June 16th, 1883.
Asst. Engr. B. C. C. & S. W. R. R.,
Philipsburg, Centre Co., Pa.

Hunter, W., April 19th, 1884.
Asst. Roadmaster P. & R. R. R.,
227 S. 4th St., Phila.

Hutchinson, Edw. S., April 7th, 1883.
Civil and Mining Engineer,
3301 Arch St., Phila.

Ingham, Wm. A., Feb. 2d, 1878.
President Rockhill Iron & Coal Co.,
320 Walnut St., Phila.

Ingles, **William**, Jan. 12th, 1884.
Asst. Engr. N. & W. R. R.,
Roanoke, Roanoke Co., Va.

Ives, **Theo. C.**, June 16th, 1883.
Resident Engineer S. Pa. R. R.,
Harrisburg, Pa.

Jamison, **Samuel**, Jan. 14th, 1882.
Civil Engineer,
2011 Arch St., Phila.

Janeway, **J. J.**, June 16th, 1883.
Div. Engr. B. C. C. & S. W. R. R.,
Philipsburg, Centre Co., Pa.

Janvier, **Thomas G.**, Jan. 14th, 1882.
Assistant Engineer Fairmount Park,
Park Office, Belmont, Phila.

Jenny, **Karl**, Jan. 14th, 1882.
Civil Engineer with Southern R. R. of Austria,
III Salesianergasse 33, Vienna, Austria.

Johnson, **Joseph**, Dec. 4th, 1880.
Surveyor and Regulator 11th Survey District, Phila.,
501 N. 40th St., Phila.

Jones, **Richard W.**, March 15th, 1884.
Asst. Engr. Brooklyn Elevated R. R.,
31 Fulton St., Brooklyn, N. Y.

Jones, **W. H.**, June 21st, 1884.
Surveyor and Regulator 12th District.
4001 Sansom St., Phila.

Jones, **Washington** (*Director*), May 6th, 1882.
Supt. Port Richmond Iron Works,
1632 N. Fifteenth St., Phila.

Kneass, **Strickland L.**, Oct. 16th, 1880.
Mechanical Engineer with Wm. Sellers & Co.,
418 S. 15th St., Phila.

Lee, **Harry K.**, Dec. 2d, 1882.
Mechanical Engineer with Hartford Engineering Co.,
Hartford, Conn.

Lee, Preston B., June 16th, 1883.
Mechanical Engineer,
3925 Lancaster Ave., Phila.

Lee, R. H., Nov. 19th, 1881.
Supt. Logan Iron & Steel Co.,
Lewistown, Pa.

Lehman, Ambrose E., Feb. 2d, 1878.
Asst. Geologist Penna. Geol. Survey,
711 Walnut St., Phila.

Lesley, Robert W., March 15th, 1884.
Hydraulic Cement Manufacturer,
312 S. 15th St., Phila.

Leuffer, Andrew B., May 1st, 1880.
Civil Engineer,
1016 Race St., Phila.

Lewis, Theo. J., March 15th, 1884.
Mech. Engr. Standard Steel Works,
220 S. 4th St., Phila.

Lewis, Wilfred, Dec. 17th, 1877.
Mechanical Engineer with Wm. Sellers & Co.,
33d and Powelton Ave., Phila.

Lillie, S. Morris, March 5th, 1881.
Chemist Franklin Sugar Refinery,
101 S. Front St., Phila.

Linton, Harvey, Jan. 12th, 1884.
Asst. Engr. Phila. Water Dept.,
13th and Spring Garden Sts., Phila.

Little, J. Kay, April 7th, 1883.
Assistant Engr. Phila. Survey Dept.,
City Hall, Phila.

Loiseau, E. F., April 7th, 1883.
Supt. Loiseau Fuel Co.,
1326 Girard Ave., Phila.

Loss, Henry W., April 19th, 1884.
Mech. Engr. Edge Moor Iron Works,
Wilmington, Del.

Lorenz, William, May 6th, 1882.
Chief Engineer Phila. & Reading R. R.,
227 S. 4th St., Phila.

Lüders, Harrison C., May 21st, 1881.
Secretary Phosphor-Bronze Smelting Co., Lim.,
206 S. 41st St., Phila.

Lüders, Theo. H., April 19th, 1884.
Supt. Phosphor-Bronze Smelting Co.,
512 Arch St., Phila.

Ludlow, Edwin, April 2d, 1881.
Supt. Union Coal Co.,
Shamokin, Pa.

Ludlow, William (*President*), Oct. 2d, 1880.
Chief Engineer Phila. Water Department,
13th and Spring Garden Sts., Phila.

Lyman, Frank, Oct. 4th, 1879.
Manager Stack Mine, Backbone, Va.,
34 Remsen St., Brooklyn, N. Y.

Maddock, Frank, Jan. 12th, 1884.
Engineer Roanoke Land & Imp. Co.,
Roanoke, Roanoke Co., Va.

Madeira, Louis C., Jr., Feb. 16th, 1878.
Civil Engineer,
322 Walnut St., Phila.

Magalhaes, Antonio C., Jan. 14th, 1882.
Civil Engineer,
Bahia, Brazil.

Marshall, Samuel R., April 19th, 1884.
Mechanical Engineer,
923 N. Broad St., Phila.

Marston, John, April 2d, 1881.
Assistant Engineer South Penna. R. R.,
Bakersville P. O., Somerset Co., Pa.

Matlack, D. J., May 21st, 1881.
Foreman of Foundry, Port Richmond Iron Works,
1515 Marshall St., Phila.

Matsdaira, T. A. M., May 17th, 1884.
City Engineer,
Bradford, Pa.

Matton, F. V., April 19th, 1884.
Mech. Engr. Harrison, Havemeyer & Co.,
239 S. 3d St., Phila.

May, DeCourcy, March 15th, 1884.
Asst. Supt. I. P. Morris Co.,
1230 Spruce St., Phila.

McClellan, Oliver E., March 1st, 1879.
Supt. Mid. Div. Penna. R. R. Co.,
Harrisburg, Pa.

McClure, James R., Feb. 5th, 1881.
Civil Engineer, P. R. R.,
233 S. 4th St., Phila.

McCollom, Thos. C., April 20th, 1878.
Civil Engineer U. S. Navy,
142 Montague St., Brooklyn, N. Y.

McFadden, Dr. Wm H., Jan. 18th, 1879.
American Meter Co.,
22d and Arch Sts., Phila.

McIlvaine, William, Jan. 13th, 1883.
Consulting Civil Engineer,
Denver, Col. 4039 Chestnut

McKee, Jos. J., March 15th, 1884.
Mechanical Engineer and Manufacturer,
Bethlehem, Pa.

Megear, Alter, May 17th, 1884.
Civil Engineer,
3306 Arch St., Phila.

Mercer, Joseph, Feb. 5th, 1881.
Surveyor and Regulator 6th Survey District, Phila.,
1845 Frankford Ave., Phila.

Merriam, Chas. A., Jan. 10th, 1880.
Supt. Northern Genl. Div. Mexican Natl. Ry.,
Laredo, Texas.

Merriman, Mansfield, June 18th, 1881.
Professor of Civil Engineering
Lehigh University, Bethlehem, Pa.

Millard, William H., March 15th, 1884.
Civil Engineer, Wilson Bros. & Co.,
435 Chestnut St., Phila.

Miller, Francis L., Jan. 10th, 1880.
Civil Engineer,
130 Hall St., Portland, Or.

Miller, Geo. L., Dec. 2d, 1882.
Civil and Mining Engineer,
Houtzdale, Pa.

Millholland, Henry, June 16th, 1883.
Mechanical Engineer,
Logan House, Altoona, Pa.

Mordecai, Augustus, March 6th, 1880.
Assistant Engineer New York, Penna. & Ohio R. R. Co.,
Cleveland, Ohio.

Morris, Gouverneur, April 2d, 1881.
Assistant Supt. Lehigh Coal and Nav. Co.,
Lansford, Carbon Co., Pa.

Morris, Henry G. (*Director*), Feb. 2d, 1878.
Mechanical Engineer and Machinist,
209 S. Third St., Phila.

Morris, Israel W., April 20th. 1878.
Treasurer Lehigh Valley Coal Co.,
238 S. 3d St., Phila.

Mucklé, John S., April 7th, 1883.
Mechanical Engineer with M. R. Mucklé, Jr.,
Rooms 16 and 17, Ledger Building, Phila.

Mucklé, M. Richards, Jr., Dec. 17th, 1877.
Engineer and Machinist,
Rooms 16 and 17, Ledger Building, Phila.

Munroe, Henry S., Feb. 5th, 1881.
Adj. Prof. Practical Mining
School of Mines, Columbia College, N. Y. City.

Murphy, Howard (*Secretary and Treasurer*), March 16th, 1878.
Civil Engineer,
326 Walnut St., Phila.
Official, Club address—1523 Chestnut Street, Philadelphia, Pa.

Murphy, John H., March 5th, 1881.
Assistant Supervisor Penna. R. R. Co.,
250 N. Duke St., Lancaster, Pa.

Naylor, John S., April 19th, 1884.
Mechanical Engineer,
Front St. and Girard Ave., Phila.

Nauman, Wm. H., July 1st, 1882.
P. A. Engineer U S. N.,
Navy Yard, Portsmouth, N. H.

Neff, Stewart S., April 19th, 1884.
Asst. Supervisor P. R. R.,
Bellefonte, Pa.

Neilson, Wm. G., Dec. 17th, 1877.
Manager Standard Steel Works,
220 S. 4th St., Phila.

Nichols, Edward, Dec. 1st, 1883.
President Ridge Valley Iron Co.,
Hermitage, Ga.

Nichols, Henry K., April 19th, 1884.
Chief Roadmaster P. & R. R. R.,
227 S. 4th St., Phila.

Norris, Thaddeus, April 20th, 1878.
Mechanical Engineer,
Wynnnewood, Montgomery Co., Pa.

Nute, John W., April 19th, 1884.
Asst. Engr. Phila. Survey Dept.,
City Hall, Phila.

Ogden, John L., May 1st, 1880.
Assistant Engineer Phila. Water Department,
72d and Greenway Ave., Phila.

Opperman, Jesse, Nov. 19th, 1881.
Assistant Engineer L. V. R. R.,
L. V. R. R Building, Buffalo, N. Y.

Osborne, J. Godolphin, May 1st, 1880.
Asst. Train Master N. & W. R. R.,
Lovely Mount, Montgomery Co., Va.

Osler, Wm. P., Feb. 5th, 1881.
Assistant Engineer Phila. Water Department,
13th and Spring Garden Sts., Phila.

Ott, C. Henry, Jan. 12th, 1884.
Civil Engineer Woodstock Iron Co.,
Anniston, Ala.

Paddock, F. L., Nov. 19th, 1881.
Asst. Engr. Phila. Water Dept.,
13th and Spring Garden Sts., Phila.

Paddock, Geo. H., June 16th, 1883.
Engineer Manayunk Sewer, Phila.,
4827 Haverford St., Phila.

Parrish, Edward, Jan. 18th, 1879.
Mgr. Brooklyn Br., Durham House Drainage Co.,
26 Court St., Brooklyn, N. Y.

Parry, William A., March 15th, 1884.
Standard Steel Works,
220 S. 4th St., Phila.

Patterson, John Curtis, July 1st, 1882.
Div. Roadmaster P. & R. R. R.,
Lebanon, Pa.

Pierce, Dwight E., Jan. 12th, 1884.
Pres. Lloyd Valve Co.,
S. Bethlehem, Pa.

Pott, John N., May 17th, 1884.
Civil and Mining Engineer,
Pottsville, Pa.

Potts, Wm. M., Feb. 2d, 1878.
Manager Isabella Furnace,
Barneston, Chester Co., Pa.

Preston, C. A., July 1st, 1882.
Supervisor Northern Central Railway,
Union Station, Baltimore, Md.

Pusey, Chas. W., Jan. 14th, 1882.
Mechanical Engineer with the Pusey & Jones Co.,
1110 Washington St.. Wilmington, Del.

Rea, Samuel, May. 6th, 1882.
Principal Assistant Engineer Penna. R. R.,
233 S. 4th St., Phila.

Reeves, David, Oct. 2d, 1880.
President Phœnix Iron Co.,
410 Walnut St., Phila.

Reilly, Wm. B., April 19th, 1884.
Mech. Engr. Jos. Oat & Sons,
232 Quarry St., Phila.

Richardson, B. Frank, Jan. 12th, 1884.
Div. Engr. Balt. & Ohio R. R.,
1604 S. 11th St., Phila.

Ridgway, Wm. H., March 5th, 1881.
Mechanical Engineer and Manufacturer,
Coatesville, Chester Co., Pa.

Roberts, Alfred R., Feb. 2d, 1878.
Civil Engineer,
310 N. 33d St., Phila.

Roberts, Geo. B., Nov. 19th, 1881.
President Penna. R. R. Co.,
233 S. 4th St., Phila.

Roberts, Percival, March 1st, 1879.
Iron Manufacturer,
261 S. 4th St., Phila.

Roberts, Percival, Jr., Dec. 17th, 1877.
Mechanical Engineer,
Pencoyd Iron Works, 261 S. 4th St., Phila.

Roberts, Thos. A., May 21st, 1881.
Supt. Mid. Div. P. & E. R. R.,
Renovo, Pa.

Robinson, Wm. H., June 21st, 1884.
Mech. Engr. Baldwin Locomotive Works,
500 N. 15th St., Phila.

Rogers, Fairman, Feb. 2d, 1878.
Civil Engineer,
202 W. Rittenhouse Square, Phila.

Rogers, T. Mellon, April 7th, 1883.
Asst. Engr. Phila. Water Dept.,
1610 Pine St., Phila.

Roney, C. H., April 2d, 1881.
Mining and Civil Engineer,
952 N. 7th St., Phila.

Root, W. J., Jan. 13th, 1883.
Mechanical Engineer with Henry R. Worthington,
238 Broadway, N. Y. City.

Rosenberg, Friedrich, Jan. 12th, 1884.
Asst. Supervisor P. R. R.,
Spruce Creek, Pa.

Rowbottom, James, March 15th, 1884.
Foreman Mach. Dept. Wm. Cramp & Sons S. & E. B. Co.,
1936 N. Front St., Phila.

Rüdiger, J. M., Jr., March 15th, 1884.
Civil Engineer,
New Baltimore, Somerset Co., Pa.

Rudderow, Morris W., Jan. 13th, 1883.
Mechanical Engineer with Geo. V. Cresson,
527 N. 19th St., Phila.

Rutter, Chas. A., Oct. 16th, 1880.
Mechanical Engineer,
424 Walnut St., Phila.

Samuel, Edward, March 16th, 1878.
Vice Pres. of Wm. Wharton, Jr., & Co., Limited,
1800 DeLancey Place, Phila.

Sanders, Richard H., Jan. 18th, 1879.
Civil Engineer and Geologist,
737 Walnut St., Phila.

Sanne, Oscar, June 21st, 1884.
Civil Engineer, Edge Moor Iron Co.,
Wilmington, Del.

Sayen, W. Henry, May 17th, 1884.
Consulting Mechanical Engineer,
107 S. 8th St., Phila.

Saylor, Francis H., March 5th, 1881.
Civil Engineer and Bridge Builder,
257 S. 4th St., Phila.

Schick, James R., April 19th, 1884.
Asst. Engineer N. & W. & S. V. R. Rs.,
Roanoke, Roanoke Co., Va.

See, Horace, Jan. 10th, 1880.
Supt. Engineer of the Wm. Cramp & Sons S. & E. B. Co.,
Foot of Norris Street, Phila.

Seitz, Earl M., May 6th, 1882.
Assistant Engineer Penna. R. R.,
Box 47, Broad St. Station, Phila.

Sellers, Coleman, Jan. 12th, 1884.
Mechanical Engineer,
1600 Hamilton St., Phila.

Sellers, Coleman, Jr., Dec. 17th, 1877.
Mechanical Engineer with Wm. Sellers & Co.,
332 N. 33d St., Phila.

Sellers, Horace W., Dec. 17th, 1877.
Mechanical Engineer,
3301 Baring St., Phila.

Sellers, Howard, Dec. 17th, 1877.
Mechanical Engineer with Wm. Sellers & Co.,
3300 Arch St., Phila.

Sellers, William, June 21st, 1884.
Mechanical Engineer,
1600 Hamilton St., Phila.

Sellers, Wm. F., Dec. 17th, 1877.
Foreman Edge Moor Iron Co.,
Wilmington, Del.

Seymour, R. C., Jan. 13th, 1883.
Mechanical Engineer with Bullock Printing Press Co.,
52 Illinois St., Chicago, Illinois.

Sheafer, Arthur W., March 1st, 1879.
Mining Engineer,
Pottsville, Pa.

Sheafer, Walter S., April 19th, 1884.
Mining Engineer,
Pottsville, Pa.

Shedaker, D. Hudson, Feb. 5th, 1881.
Surveyor and Regulator, 3d Phila. Survey District,
425 S. Broad St., Phila,

Simpson, Wm. L., April 7th, 1883.
Supt. Kensington Engine Works,
Beach and Vienna Sts., Phila.

Smedley, Samuel L., Jan. 18th, 1879.
Chief Engineer and Surveyor Phila. Survey Department.
City Hall, Phila.

Smith, Edwin F., June 28th, 1881.
Chief Engineer of Canals, P. & R. R. R.,
Reading, Pa.

Smith, Joseph S., March 5th, 1881.
Civil Engineer and Contractor,
410 Walnut St., Phila.

Smith, T. Carpenter, Oct. 2d, 1880.
Mechanical Engineer,
3303 Hamilton St., Phila.

Smith, W. Bugbee, March 5th, 1881.
Mechanical Engineer,
413 Walnut St., Phila.

Snowden, Robert P., Dec. 2d, 1882.
Assistant Engineer, Penna. R. R.,
Camden, N. J.

Soule, Richard H., Jan. 18th, 1879.
Supt. Motive Power, N. Y., W. S. & B. Ry. Co.,
Frankfort, N. Y.

Spangler, H. W., Dec. 1st, 1883.
Engineer U. S. N.,
Box 532, Carlisle, Pa.

Spencer, Graham, May 21st, 1881.
Supt. American Kaolin Works,
Kaolin P. O., Chester Co., Pa.

Stauffer, David McN., Feb. 2d, 1878.
Consulting Engr., Ed. "Engineering News,"
12 Tribune Building, N. Y. City.

Stearns, Irving A., June 16th, 1883.
Mining and Civil Engineer,
Wilkesbarre, Pa.

Stevenson, Arch. A., May 17th, 1884.
Mechanical Engineer,
1507 Locust St., Phila.

Stewart, Harry G., March 15th, 1884.
Mechanical Engineer,
1130 Mt. Vernon St., Phila.

Stewart, James M., Oct. 2d, 1880.
U. S. Asst. Engineer,
Lewes, Del.

Stewart, S. N., June 21st, 1884.
Mechanical Engineer,
3041 Dauphin St., Phila.

Stovell, Alfred B., Jan. 12th, 1884.
Mechanical Engineer,
3101 Chestnut St., Phila.

Strong, George S., May 21st, 1881.
Mechanical Engineer,
701 Chestnut St., Phila.

Taylor, Frederick W., April 20th, 1878.
Engineer Midvale Steel Co.,
Nicetown, Phila.

Taylor, P. A., March 15th, 1884.
Div. Roadmaster P. & R. R. R.,
Pottsville, Schuylkill Co., Pa.

Thayer, Russel, Feb. 5th, 1881.
Consulting Civil and Sanitary Engr. and Supt. Fairmount Park, Phila.,
232 S. 22d St., Phila.

Thiange, Edward, June 16th, 1883.
Civil Engineer,
325 Walnut St., Phila.

Thomas, Geo. C., Oct. 4th, 1879.
Sec. and Treas. Jersey City Car Wheel Fdy. and Machine Works,
P. O. Box 129 Jersey City, N. J.

Thompson, Chas. T., May 1st, 1880.
Mechanical Engineer with I. P. Morris Co.,
1057 Richmond St., Phila.

Thompson, Gaylord, May 17th, 1884.
Resident Engr. S. P. R. R.,
Everett, Bedford Co., Pa.

Titlow, J. Milton, Jan. 18th, 1879.
Principal Assistant Engineer Survey Department,
City Hall, Phila.

Towne, Linwood O., May 1st, 1880.
Assayer, Chemist, and Mining Engr.,
Rico, Colorado.

Townsend, David, Jan. 10th, 1880.
Mechanical Engineer with Bush Hill Iron Works,
1723 Wallace St., Phila.

Townsend, Henry T., Jan. 13th, 1883.
President Logan Iron & Steel Co.,
218 S. 4th St., Phila.

Townsend John W., Oct. 5th, 1878.
Asst. to President Cambria Iron Co.,
218 S. 4th St., Phila.

Trautwine, John C., Jr., Jan. 12th, 1884.
Civil Engineer,
326 Walnut St., Phila.

Trump, Michael, Jan. 10th 1880.
Asst. Supt. Pittsburgh Div. Penna. R. R. Co.,
Union Depot, Pittsburgh, Pa.

Turner, Geo, A., March 5th, 1881.
Mechanical Engineer, Locomotive Supt's. Office,
Christ Church, Canterbury, New Zealand.

Turk, Josef C., Dec. 1st, 1883.
Asst. Engr. Boston Bridge Works,
East Cambridge, Mass.

Tyson, A. Harvey, July 1st, 1882.
City Engineer,
City Hall, Reading, Pa.

Vandevanter, C. O., Dec. 2d, 1882.
Asst. Eng., East Broad Top R. R. & Coal Co.,
Orbisonia, Huntingdon Co., Pa.

Van Harlingen, M., April 2d, 1881.
Sr. Asst P. S. V. R. R.,
28 S. 5th St., Reading Pa.

Vezin, H. A., Jan. 18th, 1879.
Civil and Mining Engineer,
P. O. Box 144, Leadville, Col.

Vogdes, Jesse T., Jr., March 15th, 1884.
Asst. Engr. Fairmount Park,
629 N. 40th St., Phila.

Vogt, Axel S., Jan. 10th, 1880.
Mechanical Engineer with Schutte & Goehring,
12th and Thompson Sts., Phila.

Waddell, J. A. L., Dec. 2d, 1882.
Professor of Civil Engineering
University of Tokio, No. 5 Kaga Yashiki, Tokio, Japan.

Waddell, Robt. W., Dec. 1st, 1883.
Asst. Engr. Colorado Trust Co.,
Care Dr. Rogers, Bancroft Block, Denver, Col.

Walbridge, W. G., July 1st, 1882.
Assistant Engineer Department of Surveys,
5125 Adams St., Germantown, Phila.

Wallace, Edward R., March 15th, 1884.
Asst. Engr. B. C., C. & S. W. R. R.,
Philipsburg, Centre Co., Pa.

Warren, B. F., Feb. 16th, 1878.
Manager Ocean Oil Co., etc.
1708 Mt. Vernon St., Phila.

Webster, Geo. S., Jan. 18th, 1878.
Surveyor and Regulator 10th Phila. Survey District,
4626 Frankford Ave., Phila.

Wentworth, Chas. C., Dec. 4th, 1880.
P. A. Engineer Construction Department, N. & W. R. R.,
Roanoke, Roanoke Co., Va.

West, Preston C. F., March 5th, 1881.
Civil and Mining Engineer, Calumet and Hecla Mine,
Calumet, Houghton Co., Mich.

Wetherill, W. C., May 6th, 1882.
Locating Engr. Beech Creek, Clearfield & S. W'n. R. R.,
Philipsburg, Centre Co., Pa.

Wharton, William, Jr., March 15th, 1884.
Engineer and Manufacturer,
Cottage Lane, Germantown, Phila.

Wharton, W. Rodman, Jan. 18th, 1879.
Mechanical Engineer,
911 Pine St., Phila.

White, Arthur M., Dec. 2d, 1882.
Supt. New York Locomotive Works,
Rome, N. Y.

Whiting, Stephen B., April 19th, 1884.
Gen'l Manager P. & R. Coal and Iron Co.,
Pottsville, Pa.

Williamson, T. Roney, Jan. 10th, 1880.
Architect,
Room 26, Merchants' Exchange, 3d and Walnut Sts., Phila.

Wilson, E. A., Jan. 12th, 1884.
Engr. in charge C. C. Ext., N. R. Div., N. & W. R. R.,
Pulaski, Pulaski Co., Va.

Wilson, J. Chester, April 19th, 1884.
Gen'l Manager Novelty Electric Co.,
5th and Locust Sts., Phila.

Wilson, John A., Jan. 18th, 1879.
Civil Engineer,
435 Chestnut St., Phila.

Wilson, Joseph B., May 17th, 1884.
Iron,
209 S. 3d St., Phila.

Wilson, Joseph M., June 21st, 1884.
Civil Engineer and Architect,
435 Chestnut St., Phila.

Wingate, J. H., May 6th, 1882.
Civil Engineer,
Wytheville, Va.

Winslow, Arthur, Jan. 13th, 1883.
Geologist,
64 Dudley St., Boston Highlands, Mass.

Wister, Jones, April 19th, 1884.
Metallurgist,
230 S. 4th St., Phila.

Wood, James F., June 21st, 1884.
Mechanical Engineer and Contractor,
12th and Thompson Sts., Phila.

Wootten, Frederic C., March 15th, 1884.
Asst. Road Foreman of Engrs. P. R. R.,
226 N. 6th St., Reading, Pa.

Worrall, James, Oct. 2d, 1880.
Civil Engineer,
Harrisburg, Penna.

Yocum, Jacob H., May 21st, 1881.
Engineer Water Works,
Box 14, Columbus, Ga.

Young, Chas. A., Dec. 17th, 1877.
Geologist,
100 Troost Ave., Kansas City, Mo.

Ziegler, Wm. L., Jan. 14th, 1882.
Engineer of Construction Penna. R. R.,
Broad St. Station, Phila.

Zook, M. A., April 7th, 1883.
Engineer Indianapolis Union Ry.,
Indianapolis, Ind.

DECEASED MEMBERS.

With date of election and of decease.

HONORARY MEMBER.

Trautwine, John C.,	Civil Engineer.	Jan. 10th, 1880. Sep. 14th, 1883.

CORRESPONDING MEMBERS.

Fry, H.,	Mechanical Engineer.	Feb. 16th, 1878. April 27th, 1883.
McIlvaine, Rodman,	Civil Engineer.	Feb. 16th, 1878. Oct. 7th, 1878.

ACTIVE MEMBERS.

Billin, Wm. L.,	Mining Engineer.	June 18th, 1881. Jan. 24th, 1883.
Cartwright, Henry,	Civil Engineer.	Jan. 18th, 1879. June 30th, 1881.
Kneass, Strickland,	Civil Engineer.	Jan. 18th, 1879. Jan. 14th, 1884.
Knight, J. B.,	Mechanical Engineer.	April 6th, 1878. Mch. 10th, 1879.